



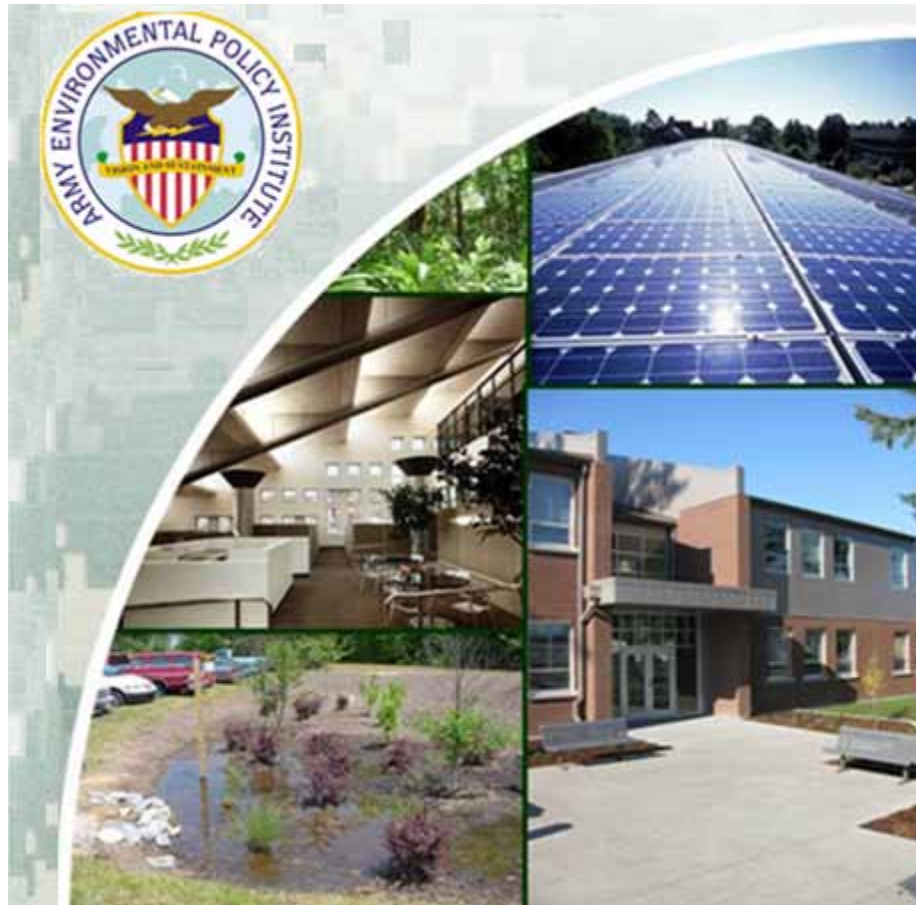
**US Army Corps
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Center for the Advancement of Sustainability Innovations (CASI)

The Value of “Green” to the Army

Thomas R. Napier, Annette L. Stumpf, Richard L. Schneider,
Samuel L. Hunter, Elisabeth M. Jenicek, and Dahtzen Chu

March 2011





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Information for the Center for the Advancement of Sustainability Innovations can be found at:
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Final Report

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Abstract: Over the past few years, the U.S. Army has planned, designed, and built many new facilities were using the Leadership in Energy and Environmental Design (LEED) rating tool as a guide and measurement. There is now a need to determine whether this change in business practice has actually resulted in better buildings, buildings of greater value to the Army. This work was undertaken to begin to determine the value of “green” to the Army by developing a valid, reliable, and meaningful method to compare “pre-green” buildings to recent “green” buildings. This work began to establish the metrics that can be used to compare facilities in a meaningful way; to determine whether the Army is getting a good return on the investment of time and money spent to build sustainable, green buildings; to measure whether the outcome is improving over time; and ultimately, to describe a potential method for assessing the value of “green” facilities to the Army, and the context in which that method will be applied.

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Preface

This study was funded by and conducted for the Army Environmental Policy Institute (AEPI), by the Center for the Advancement of Sustainability Innovations (CASI). Mr. Michael L. Cain is the Director of AEPI. CASI was established by ERDC, in October 2006, to help enable the U.S. military to proactively respond to current and emerging sustainability challenges. Ecosystem services are one of the CASI technology focus areas. The technical monitor was John J. Fittipaldi, Senior Fellow, AEPI.

The work was completed by the Engineering Processes Branch (CF-N) and the Energy Branch (CF-E) of the Facilities Division (CF), Construction Engineering Research Laboratory (CERL). The ERDC-CERL Principal Investigator (PI) was Thomas Napier, CF-N. Donald K. Hicks is Chief, CF-N, and Franklin H. Holcomb is Acting Chief, CF-E. Dr. John Bandy is Chief, CEERD-CN and L. Michael Golish is Chief, CEERD-CF. The Director of CASI is Mr. William D. Goran, and Michelle Hanson is the Associate Director. The Director of AEPI is Michael L. Cain. The Director of ERDC-CERL is Dr. Ilker R. Adiguzel.

CERL is an element of the U.S. Army Engineer Research and Development Center (ERDC), U.S. Army Corps of Engineers. The Commander and Executive Director of ERDC is COL Gary E. Johnston, and the Director of ERDC is Dr. Jeffery P. Holland.

1 Introduction

Background

Much has been said recently about the desire of the Army to build sustainable or “green” facilities to meet mission objectives, reduce its environmental footprint, improve occupant productivity, and minimize energy consumption. Before 2006, the Army used the “SPiRiT” (Sustainable Project Rating Tool) green building rating tool. Since 2006, the Army has used the U.S. Green Building Council’s rating tool, LEED (Leadership in Energy and Environmental Design) to guide the planning, design, and construction of new facilities.

The use of LEED was systematically implemented in the Corps of Engineers business process during the Military Construction (MILCON) delivery process (MILCON Transformation), which was initiated in fiscal year 2005 (FY05). MILCON Transformation was a complex process change in which the Corps of Engineers reduced costs and complexity of requirements by transitioning to Design-Build and adopting building codes and specifications used in commercial construction markets instead of Army unique requirements. In a Design-Build project, the contractor performs design and construction services under one contract according to Government-specified criteria. This contrasts with the traditional Design-Bid-Build process whereby the contractor constructs a design developed independently by an architectural/engineering firm under Government oversight.

LEED emerged as the consensus rating tool of choice that was adopted by Federal, state, local, and commercial entities. The Army has been requiring new facilities to be LEED Silver “certifiable.” Although these facilities are not actually submitted to the U.S. Green Building Council (USGBC), they would achieve a Silver rating if they were. (A 2-year U.S. Army Corps of Engineers [USACE] validation study confirms they do meet the Silver criteria.) However, 5 percent of new Army buildings must be submitted and certified by the Green Building Certification Institute (GBCI) to achieve a LEED Silver rating.

Over the past few years, many new facilities were planned, designed, and built using the LEED rating tool as a guide and measurement. Some notably successful projects exceeded expectations, while others merely met

the minimum requirements. During this time, the MILCON delivery process has been adjusted to improve the outcome and quality of buildings delivered by the private sector contractors who build Army facilities.

Yet there is still a need to determine whether this change in business practice has actually resulted in better buildings, buildings of greater value to the Army. Determining the value of “green” to the Army requires a valid, reliable, and meaningful method to compare “pre-green” buildings to recent “green” buildings. In this context, the concept of “value” must not be limited to metrics that are quantifiable in dollars (i.e., first cost to the Government, or life cycle cost), but must also include societal and environmental values, e.g., “metric tons of carbon equivalent,” or “global warming potential,” which are equally important, but cannot always be quantified in dollar terms, especially at a building or project level.

This work was undertaken to address that need by establishing the metrics that can be used to compare facilities in a meaningful way; to determine whether the Army is getting a good return on the investment (ROI) of time and money spent to build sustainable, green buildings; to measure whether the outcome is improving over time; and ultimately, to describe a potential method for assessing the value of “green” facilities to the Army, and the context in which that method will be applied.

Objective

This work was undertaken to describe a potential method for assessing the value of “green” facilities to the Army.

Scope

The scope of this work was limited to buildings and building sites (as opposed to installations, communities, or regions). This scale was chosen as a point of departure for the discussions presented herein, and because the Army manages its facility programs on a project-by-project basis. However, there is bound to be some overlap with installation, community, or regional performance. Where information about community or regional development is relevant, it will be included within the context of buildings and building sites.

It is important to view “green” as a holistic topic, not simply a collection of independent features or behaviors. Addressing environmental performance on a programmatic (i.e., community or regional) scale provides

opportunities to address environmental performance not considered at a single buildings or project scale. These include green energy generation, water resource management, transportation, air emissions, habitat and ecosystems, and other larger scale issues.

Mode of technology transfer

This report will be made accessible through the World Wide Web (WWW) at URL: <http://www.cecer.Army.mil>

2 Green Building

Definition

“Sustainable building” or “high performance building” is commonly referred to today as “green building.” Definitions of green building practices abound today, but all evolve around the environmental impact of the built environment. The U.S. Environmental Protection Agency (USEPA) defines green building as:

the practice of creating structures and using processes that are environmentally responsible and resource-efficient throughout a building's life-cycle from siting to design, construction, operation, maintenance, renovation and deconstruction.

The USGBC indicates that the intent of green building is “to significantly reduce or eliminate the negative impact of buildings on the environment and on the building occupants.” The USGBC also states that, “Green design not only makes a positive impact on public health and the environment, [but] it also reduces operating costs, enhances building and organizational marketability, potentially increases occupant productivity, and helps create a sustainable community.” The Whole Building Design Guide (WBDG) uses the term “sustainable design” and indicates that its intent is “to avoid resource depletion of energy, water, and raw materials; prevent environmental degradation caused by facilities and infrastructure throughout their life cycle; and create built environments that are livable, comfortable, safe, and productive.”

While definitions abound, experts generally agree on the basic attributes of the green building process. The USEPA has organized green building attributes by environmental impact: Aspects of Built Environment, Consumption, Environmental Effects, and Ultimate Effects. The USGBC has organized these attributes in five major credit categories: (1) Sustainable Sites, (2) Water Efficiency, (3) Energy, and (4) Atmosphere, Materials and Resources, and (5) Indoor Environmental Quality (IEQ). The WBDG outlines another approach that defines these attributes according to six major principles: (1) Optimize Site/Existing Structure Potential, (2) Optimize Energy Use, (3) Protect and Conserve Water, (4) Use Environmentally Preferable Products, (5) Enhance IEQ, and (6) Optimize Operational and Maintenance Practices.

Different organizations and sources describe “green” in somewhat different, but not dissimilar ways. Appendix A lists environmental attributes as described by the Army Annual Sustainability Report, the Global Reporting Initiative, Pacific Northwest National Laboratory (PNNL), American Society of Testing and Materials (ASTM) standard E-2432, and the U.S. Department of Energy (USDOE) Federal Energy Management Program (FEMP).

This work takes a slightly different approach to identifying and organizing the environmental performance attributes defining “green building.” First, attributes have been limited to buildings and their immediate sites. Selecting sites is not considered as part of a “building” design and construction decisionmaking process. Supporting infrastructure (utilities, transportation systems, others) are also not included. Seven major attributes have been identified: (1) Project innovation, (2) Land/site, (3) Water, (4) Building energy, (5) Air and atmosphere, (6) IEQ, and (7) Materials and resources. Second, attributes have been identified to structure a cost/benefit or return-on-investment type of analysis (explained in Chapter 4).

Army drivers

For the Army, many drivers shape the question “How green is green?” Most of these drivers are:

- *Energy Policy Act of 2005 (EPAct05)*, 8 August 2005
- *The Federal Leadership In High Performance and Sustainable Buildings*, Memorandum of Understanding, 06 January 2006
- Executive Order (EO) 13423, *Strengthening Federal Environmental, Energy, and Transportation Management*, January 2007
- Deputy Assistant Secretary of the Army, Installations and Housing (DASA[I&H]), Memorandum, *Sustainable Design and Development Policy Update – Life-Cycle Costs*, 27 April 2007
- Energy Independence Security Act 2007 (EISA 2007), 19 December 2007
- EO 13514, *Federal Leadership in Environmental, Energy & Economic Performance*, 8 October 2009
- Office of the Under Secretary of Defense Office of the Secretary of Defense (OSD), Memorandum, *DoD Implementation of Storm Water requirements under Section 438 of the Energy Independence and Security Act (EISA)*, 19 January 2010

- Office of the Assistant Chief of Staff for Installation Management (OACSIM), Memorandum, *Constructive Use of FY2010 and Future Bid Savings*, 12 May 2010
- U.S. Army Corps of Engineers Engineering and Construction Bulletin, *Improving building performance through enhanced requirements for energy performance and select LEED credits*, 28 June 2010
- DASA (I&H) Memorandum, *Sustainable Design and Development Policy Update* (Environmental and Energy Performance), 08 July 2010.

The DASA (I&H) 08 July 2010 Memorandum, which updates the *Sustainable Design and Development Policy* is by far the most current and most important Army facilities sustainable design and development update. It is applicable to all construction activities in the United States and its territories on permanent Active Army installations, Army Reserve and Army National Guard Centers, and Armed Forces Reserve Centers, regardless of funding source. Further it directs the incorporation of all EAct05, EISA07, EO 13423, and EO 13514 and statute high performance building requirements in Army new buildings, structures, and major renovations.

The DASA (I&H) memo is broad in the scope of its coverage requiring that Energy Efficiency, Metering, Solar Hot Water Heating, Storm Water Management, Indoor Water Consumption, Outdoor Water Consumption, and Measurement and Verification (M&V) measures be incorporated in all Army projects starting with FY13 military construction program and FY13 Sustainment, Restoration, and Modernization (SRM) program where life cycle cost effective.

In addition, the DASA (I&H) memo updates Army policy on the use of LEED for new construction and renovation, establishes Army policy on the use of LEED Homes, and clarifies the use of LEED for existing buildings. It addresses the application of Life-Cycle Cost Analysis (LCCA) to Army projects, requires the inclusion of LEED assessment in Request for Proposal (RFP) requirements for all projects using the design/build procurement method, and requires the inclusion of full estimated costs associated with achieving this policy in the project DOD Form 1391s. It closes stressing that High-Performance buildings are critical to cost effective life cycle management of Army infrastructure and national energy security and that the Army must continue to develop and implement sustainability objectives into Army facilities, installations, and infrastructure to meet energy security and independence goals.

The OACSIM Memorandum of 12 May 2010 requests USACE to use new construction bid savings due to a favorable competitive environment to be applied to reducing energy and potable water consumption and managing and making beneficial use of storm water in new facilities. It also requests building performance be monitored to validate the expected performance is being achieved.

3 Green Building State of Knowledge

General

The state of green building knowledge is significant, but still acknowledged to be incomplete. A considerable amount of literature includes design and technical guidance for developing green building designs. Cost has been a subject of interest from the beginnings of green building practice. However, the bulk of existing literature focuses on the cost of implementing green features, or in other words, the cost of construction. An awareness of longer-term costs and benefits has always existed, although experiential information and actual life cycle cost data have been limited. Some of the more recent cost-of-LEED studies do address operational costs; primarily energy and water consumption.

If life cycle costs for facilities were monitored and documented in a consistent and comprehensive fashion, the savings accrued through some initial investment would be clearly recognized. It would be easy to support an initially higher cost of energy efficient heating or cooling equipment, for example, if that cost were recovered in a short period of time, and subsequent energy savings are shown to accrue to the facility's owner.

The green building community is now becoming aware that validating in-place building performance is important. Design intent is one thing, but executing the intent during construction and preserving it throughout the occupancy and end-of-life phases is another. The traditional facility design and construction process does not lend itself to continuity in monitoring performance and life cycle cost. A facility's owner, designer (architect/engineer), construction contractor and specialty contractors, facility managers and occupants are typically of different organizations. Responsibilities are fragmented among the participants; there is usually no single responsibility to monitor performance throughout design, construction, commissioning, occupancy, repair and replacement, and building disposal. This situation is further complicated where an independent commissioning agent, USACE design and construction agent, contracted facility management service, and installation Public Works contracting office all have some participation in placing and managing Army facilities.

LEED-NC (New Construction) includes prerequisites and credits for commissioning, enhanced commissioning, and M&V, in which M&V

covers 1 year and enhanced commissioning begins within 10 months of occupancy. LEED-EB (Existing Building) includes prerequisites and credits for existing building commissioning, and performance measurement over specified time periods. However, these requirements do not constitute a full, long-term life cycle cost monitoring and analysis, nor do they address other areas of life cycle environmental performance.

The following section gives 20 examples selected to represent several types of information related to green building cost and performance. (Appendix B includes an extended summary.) Most describe modest costs for implementing green building features and positive cost/benefit results. Most focus on the characteristics that can be measured, and to which monetary costs or savings (primarily energy use, and sometimes water use) can be assigned. These studies describe favorable results. However, it would be overly optimistic to assume these studies represent the entire U.S. building stock, or that similar results can or cannot be achieved for any new construction projects.

Note that many of these studies have been conducted within the past 2 or 3 years. This suggests a recent increase in the interest in estimating and measuring actual green building performance within the green building community.

As discussed above, the LEED rating system describes “green” in four increments: Certified, Silver, Gold, and Platinum. Intuitively, one would assume each successive level requires successively greater cost to achieve the level, and each successive level will result in better life cycle environmental performance. The case studies described below generally support the assumption. However, it is important to realize that achieving a LEED rating can be accomplished in a variety of ways, e.g., by achieving different combinations of credits (i.e., green building features).

Furthermore, one must also realize not all green building features incur equal cost, nor do they result in equal environmental or economic benefit. Many LEED credits (i.e., green building features) can be implemented at a low or modest initial cost. Some, such as renewable energy systems, are very expensive to install and have long payback periods. Therefore, the relationships between environmental performance, costs associated with LEED ratings, and long-term environmental and economical performance are not strictly defined.

Estimated green building costs

Building for Sustainability: Six Scenarios for the David and Lucile Packard Foundation. Los Altos Project. 2002.

The David and Lucile Packard Foundation developed a decisionmaking guide that would describe the aesthetic, economic, schedule, and environmental impacts implied by each LEED rating level compared to a base building design. Energy performance for each level was also modeled. Achieving LEED ratings is estimated to be more costly than a conventional baseline building, as follows:

- Certified: 1.5 percent
- Silver: 13.5 percent
- Gold: 15.8 percent
- Platinum: 22.2 percent.

Estimated energy consumption were calculated to be reduced compared to a conventional baseline building, as follows:

- Certified: 49.2 percent
- Silver: 93 percent
- Gold: 98 percent
- Platinum: 96 percent.

GSA LEED® Cost Study. Steven Winter and Associates. October 2004.

The U.S. General Services Administration (GSA) estimated construction costs for two U.S. Courthouse construction scenarios, one to retrofit existing buildings, the other to construct new buildings. The cost estimating models for retrofitting an existing courthouse determined that LEED ratings could be achieved at the following costs above a baseline cost:

- Certified: –0.4 to a 1.0 percent
- Silver: –0.03 to 4.4 percent
- Gold: 1.4 to 8.1 percent.

The cost estimating models for constructing a new courthouse determined the following LEED ratings could be achieved at the following costs above a baseline cost:

- Certified: 1.4 to 2.1 percent
- Silver: 3.1 to 4.2 percent
- Gold: 7.8 to 8.2 percent.

Estimated or modeled savings

***Energy Savings and Performance Gains in GSA Buildings: Seven Cost-Effective Strategies.* GSA Public Building Service. March 2009.**

The GSA Public Building Service (PBS) surveyed 22 buildings in the United States and made seven recommendations for reducing electrical energy use. Through energy modeling, PBS concluded that an annual savings of over 568 million kWh was possible compared to non-LEED buildings.

***Improving the Energy Performance of Buildings Learning from the European Union and Australia.* Charles P. Ries, Joseph Jenkins, and Oliver Wise. Rand Corporation. 2009.**

This study examined the impact that energy related policies and regulations have on European Union and Australian Commonwealth buildings. The study concluded that regulations and building codes can be applied to building owners, but that building occupants have the greatest impact on actual in-place energy performance such as disabling automatic thermostats or leaving windows open during heating seasons. Media campaigns, tenant training, and expert certification programs were recommended.

***Climate Friendly Buildings and Offices: A Practical Guide.* A United Nations Environment Programme Report. 2010.**

This guide provides recommendations for reducing Greenhouse Gas (GHG) emissions in United Nations (UN) buildings by reducing energy consumption. The conclusion is that from 30 to 50 percent of current GHG emissions can be eliminated by reducing energy consumption. The investment cost to achieve these savings would not be significant.

Actual building and data comparisons

***Facilities Management Resources Sustainability: The Economics of LEED® – Existing Buildings (EB).* Michael Army. Leonardo Academy.* 2009.**

Twenty-three existing buildings were surveyed and data were collected for LEED certification, implementation, and building operating costs. This study concluded that implementing the LEED-EB levels (including the cost of preparing documentation and submittals to USGBC) would cost:

- Certified: 1.60/sq ft
- Silver: \$1.22/sq ft
- Gold: \$1.73/sq ft
- Platinum: \$1.84/sq ft.

* Leonardo Academy is a charitable non-profit organization dedicated to advancing sustainability and putting the competitive market to work on improving the environment.

Intuitively one would think the per-square-foot prices for achieving successively more challenging LEED levels would be successively higher per level. The LEED-EB Silver cost is less than the Certified cost, which is contrary to expectations. However, the Army Study does not provide any explanation for these results.

The survey also demonstrated that many of the measures in LEED®-EB are “low” and “no cost” to implement, thereby lowering the implementation costs.

Operating and maintenance costs were slightly lower for LEED-EB buildings compared to non-LEED buildings, but utility costs were 16 percent lower than non-LEED buildings. Other benefits to the buildings’ owners, such as occupant satisfaction, were also achieved.

“Review of the LEED Points Obtained by Canadian Building Projects.”
Journal of Architectural Engineering. Lucas Da Silva and Janaka Y. Ruwanpura. American Society of Civil Engineers. June 2009.

This paper collected and analyzed information from 42 LEED new construction projects across Canada. They tabulated the most often awarded points, as well as those that are granted the least frequently. The credits with the highest percentage of use were:

- ID1.1 and ID2 (innovation in design and LEED® accredited professional); 100 percent
- WE3.1 (water use reduction, 20 percent); 98 percent
- MR5.1 (local/regional materials, 10–20 percent manufactured locally): 98 percent
- SS4.2 (bicycle storage and change rooms): 98 percent
- WE1.1 (water efficient landscaping, reduced by 50 percent): 95 percent
- ID1.2 (innovation in design 2): 95 percent.

The credits with the lowest percentage of use were:

- MR1.3 (building reuse, maintain 50 percent of interior non-structured elements): 0 percent
- MR1.2 (building reuse, maintain 95 percent of existing walls, floors, and roof): 2 percent, and
- MR6 (rapidly renewable materials): 5 percent
- EA2.3 (renewable energy, 20 percent): 5 percent
- MR1.1 (building reuse, maintain 75 percent of existing walls, floor, and roof): 5 percent.

***Costing Green: A Comprehensive Cost Database and Budgeting Methodology.* Lisa Fay Matthiessen and Peter Morris. Davis Langdon and Associates. July 2004.**

This study evaluated the LEED® implementation cost for new construction of Academic buildings, Laboratories, and Libraries. It found that there is no significant statistical difference between the average implementation costs per square foot for LEED versus non- LEED buildings. The points most frequently awarded were:

- ID2 (innovation in design and LEED® accredited professional)
- IE3.1 (Construction Management indoor air quality (IAQ) plan during construction)
- IE3.2 (Construction Management IAQ plan before occupancy)
- IE4.1 (Low Emitting Materials adhesives and sealants)
- IE4.2 (Low Emitting Materials paints and coatings)
- IE4.3 (Low Emitting Materials Flooring Systems)
- MR2.1 (Construction Waste Management diverting 50 percent from landfill).

The credits with the lowest percentage of use were:

- MR1.1 (Building reuse, maintain 75 percent of existing walls, floor, and roof)
- MR1.2 (building reuse, maintain 95 percent of existing walls, floors, and roof)
- MR1.3 (Building reuse, maintain 50 percent of interior nonstructural elements)
- MR3.2 (Resource reuse, 10 percent)
- SS3.0 (Brownfield redevelopment)
- EA5.1 (Measurement & verification).

***Greening America's Schools: Costs and Benefits.* Gregory Kats and Jon Braman. A Cap E report for U.S. Green Building Council. October 2006.**

This report draws data from 30 green schools built in 10 states and compares costs data with conventional school designs. Some of the costs are based on actual building performance, while some new school buildings' costs are based on modeling and engineering estimates. Findings were:

- Four of the green schools cost no more than conventionally designed schools.
- The average green school cost 1 to 2 percent more than that of conventionally designed schools, or about \$3/sq ft.

- Six schools cost at least 3 percent more than conventionally designed schools.
- One school (in Hawaii) cost 6.3 percent more than the national baseline. (Note that construction prices in Hawaii are 17 percent higher than the U.S. national average.)
- Green schools use an average of 33 percent less energy and 32 percent less water than conventionally designed schools.
- Improved teacher retention, and lowered health costs saved green schools directly \$12/sq ft, about four times the cost of implementing the green designs.
- The green schools provide financial benefits that are 20 times as large as the invested cost, or about \$70 per sq ft.

This study determined the cost of “going green,” as they put it, was approximately \$3/sq ft. The economic benefits are \$74/sq ft, resulting in a net benefit of over \$70/sq ft, or over 20 times the initial investment. Economic benefits were calculated for the following: reduced energy and water consumption; reduced air and water emissions; increased earnings; asthma reduction; cold and flu reduction; teacher retention; and employment impact. Note that not all of these benefits accrue directly to the schools. Reduced air emissions is a societal benefit, and employment impact is a community economic benefit.

This study also cites research by Carnegie Mellon University that quantifies health gains from improved indoor air quality, productivity gains from improved temperature controls, productivity gains from high performance lighting systems, and job impacts of waste diversion versus disposal.

***Assessing Green Building Performance: A Post Occupancy Evaluation of 12 GSA Buildings.* Kim M. Fowler and Emily M. Rauch. PNNL. July 2008.**

In 2007, GSA evaluated the sustainability impacts of 12 LEED-rated buildings throughout the United States compared to calculated non-LEED baselines. This study concluded that:

- 75 percent of the buildings consumed less energy than baseline buildings
- 67 percent of the buildings consumed less water than the baseline buildings
- 100 percent of the buildings resulted in a higher occupant satisfaction
- 66 percent of the buildings experienced a 13 percent reduction in operating and maintenance costs.

Doing Well by Doing Good? An Analysis of the Financial Performance of Green Office Buildings in the USA. Piet Eichholtz, Nils Kok, and John Quigley.

This project evaluated 694 LEED-rated buildings and 7488 control buildings within close proximity of the rated buildings. The object was to assess the effect that LEED rating had on contract and effective rents. This study concluded that:

- LEED-rated buildings commanded 2 percent higher rental rates than non-LEED control buildings.
- Occupancy levels were over 6 percent higher than non-LEED buildings.

The study also concluded there is a potential to reduce energy and water use and waste, improve employee productivity through an improved Indoor Environment Quality, improve corporate image of the tenants, and lower depreciation and market volatility.

Energy Performance of LEED® for New Construction Buildings: Final Report. Cathy Turner and Mark Frankel. New Building Institute. 04 March 2008.

This study analyzes the measured energy performance for 121 new LEED-rated commercial buildings, comparing actual energy performance to the modeled energy performance and to prevailing energy code requirements. The study found that, for all 121 buildings the median measured, energy consumption was:

- 24 percent lower than the national average for commercial buildings
- 28 percent lower than energy code minimum requirements.

Greening Our Built World, Costs, Benefits, and Strategies. Greg Kats, Jon Braman, and Michael James. Island Press, 2010.

This book evaluates 186 buildings in nine countries to determine whether the benefits of green design outweigh the costs, and what impact could be made on energy use and global warming. Compared to non-LEED rated buildings, this study found:

- A median cost increase of 1.5 percent (range 0 – 18 percent) for new green construction
- A median cost increase of 1.9 percent for upgrading existing buildings
- The median reduction in energy use was 34 percent (range of \$0.20-\$1.00/sq ft)
- The median reduction in water use (median values) was 39 percent (range of \$0.50-\$2.00/sq ft)
- GHG cost reduction of \$1.00 – \$2.00/sq ft (at \$20/ton CO₂E value)

- Reduction of 50 tons of SO₂ per house annually
- Reduction of 24,000 tons of CO₂ per house annually.

High Performance Green Buildings: What's it worth? Investigating the Market Value of High Performance Green Buildings. Theddi Wright Chappell, Chris Corps, and Brandon Smith. May 2009.

Three renovated office complexes were studied in the Pacific Northwest to compare the relative values of high performance office buildings with standard building design and construction. The study found:

- Implementation cost increase (all buildings): 0.2 percent of total construction cost
- Energy savings: range of 3.29 – 23 percent
- Water savings: range of 21 – 30 percent
- Storm water runoff reduction: 50 percent.

LEED Building Performance in the Cascadia Region: A Post Occupancy Evaluation Report. Cathy Turner. Prepared for the Cascadia Region Green Building Council. 2006.

This study evaluated energy and water use in 11 buildings; actual versus design, actual compared to a baseline and actual compared to a regional average. The study did not include any cost data.

- Energy savings: 40 percent less than baseline models
- Most green buildings used slightly more water, which was attributed to irrigating new landscape materials.

Managing the Cost of Green. Geoff Syphers, Mara Baum, Darren Bouton, and Wesley Summons. October 2003.

This report addressed economics in design and construction of green buildings. Implementation costs compared to baseline costs were:

- Certified: 0 – 2.5 percent
- Silver: 0 – 3.4 percent
- Gold: 0.5 – 5.0 percent
- Platinum: 4.6 – 8.5 percent.
- Investing in additional design effort, resulting in a 3 percent increase in design fees, can reduce green building construction cost by 10 percent.
- Maintaining collaboration with the Mechanical/Electrical/Plumbing (MEP) designer throughout the design process would reduce the MEP construction cost another 10 percent.
- Including optional bid items for LEED credits increases construction cost more than incorporating them as base bid items.
- The cost of implementing LEED credits can also be reduced through a Design-Build process.

***Occupant Satisfaction with Indoor Environmental Quality in Green Buildings.* S. Abbaszadeh, L. Zagreus, D. Lehrer, and C. Huizenga. Center for the Built Environment. University of California. 2006.**

The Center for the Built Environment conducted a survey to assess the IEQ of 21 LEED-rated buildings and 160 baseline office buildings. The survey measures occupant satisfaction and self-reported productivity in IEQ categories. This study found that occupants in LEED-rated buildings reported higher satisfaction in most, but not all IEQ categories. No data on investment were collected.

***Regional Green Building Case Study Project: A Post-Occupancy Study of LEED® Projects in Illinois.* Final Report Fall 2009. The Grand Victoria Foundation, supported by USGBC.**

This case study analyzed the post-occupancy performance, costs, and benefits of 25 LEED-rated buildings mostly in the greater Chicago, IL area for a year. The study found all buildings' performance was better than the regional average:

- Additional cost to implement: 3.8 percent
- Energy reduction from regional average: 5 percent
- Water reduction from regional average: "Better"
- Occupant satisfaction and IEQ were also higher than the regional baseline.

***The Costs and Financial Benefits of Green Buildings: A Report to California's Sustainable Building Task Force.* Greg Kats, Leon Alevantis, Adam Berman, Evan Mills, and Jeff Perlman. October 2003.**

California's Sustainable Buildings Task Force analyzed in-place cost and performance data for 33 LEED-rated buildings. Data were also available for similar non-LEED buildings as a basis of comparison.

- Additional cost to implement (average): 2 percent
- C&D waste reduction: Minimum of 50 percent, or \$0.50/sq ft
- Energy savings (actual): 30 percent less than conventional buildings
- Water savings (projected from actual): \$0.51/sq ft net present value over 20 years
- GHG reduction (calculated): \$1.18/sq ft net present value over 20 years, based on carbon value of \$5.00/ton
- Occupant productivity increase: 1.5 percent, or \$998/yr/occupant, or \$36.89/sq ft.

Achieving Silver LEED: Preliminary Benefit-Cost Analysis for Two City of Seattle Facilities Final Report. SBW Consulting, Inc. Seattle Office of Sustainability and Environment. April 2003.

The purpose of this study was to evaluate the impacts of the Sustainable Building Policy on two projects nearing completion in early 2003: the City of Seattle's Justice Center and Marion Oliver McCaw Performance Hall. The analysis concluded that the City of Seattle's investment of an additional \$2.64 million to obtain LEED Silver certification for the Justice Center and McCaw Hall projects is cost-effective when examined over a 25-year period.

- Additional cost to implement (two buildings combined): 1.2 percent
- Of the 1.2 percent additional cost:
 - 56 – 67 percent was attributed to LEED Energy & Atmosphere credits
 - 11 – 20 percent was attributed to LEED IEQ credits
 - 13 – 29 percent was attributed to LEED Innovation & Design Process credits
 - A negligible amount was attributed to Water Conservation credits.
- Total economic savings (estimated over 25 years): \$8.52 – \$12.36/sq ft net present value, depending on the discount rate used in the calculation.
- Direct operating savings (estimated over 25 years): \$4.27 – \$6.19/sq ft net present value, depending on the discount rate.

Conclusions

Virtually all the case study analyses were developed in the context of achieving LEED certification at some level. This is the de facto definition of “green” for the purposes of the studies.

Virtually all the case study analyses cite an increase in project cost associated with green (i.e., LEED-rated) building. Studies that described buildings simply as “green” or “LEED-rated” indicated a cost increase ranging from 1 – 6.8 percent, with a “typical” cost increase of about 2 percent. Studies that distinguished among the LEED levels indicated these cost increases:

- Certified: 0 – 15 percent, with a “typical” increase of about 2 percent
- Silver: 0 – 13.5 percent, with a “typical” increase of about 3 percent
- Gold: 0.5 – 15.8 percent, or a “typical” increase of about 6.5 percent
- Platinum: 4.6 – 22.2 percent, or a “typical” increase of about 8 percent

The two sources addressing upgrades to existing buildings suggested implementation of a LEED-EB level could be achieved a somewhat lower price than for new construction. Unfortunately, each measured the cost of implementation in different units of measure. One study reveal LEED-EB was implemented at a range of \$1.60/sq ft to \$1.84 (Certified to Platinum), the other 0.2 percent of the total construction cost. Many LEED credits were described as being achievable at little or no additional cost.

One study addressed implementation in other than construction cost alone, indicating design and contracting practices can have an impact on overall project cost. Collaborative design (specifically with the energy systems design professionals), bid schedule development, and project delivery method were addressed. This study concluded that Design-Build project delivery would result in lower costs for LEED-rated buildings than conventional design-bid-build delivery.

Virtually all the case study analyses comparing green and non-green buildings (i.e., LEED-rated and non-LEED rated) reveal that green buildings perform better than non-green buildings. The metric for this evaluation almost always includes energy and water use savings, both in modeled performance and in actual measured performance. Studies indicated an energy savings ranging from 16 – 33 percent, with a “typical” energy savings of about 30 percent. Studies indicated a water savings of over 30 percent was also typical. It must be noted that some buildings did not exhibit water savings.

The sustainability of building sites was not addressed in any of the case studies or literature cited. The opportunity exists to evaluate sustainability performance on a programmatic scale, and contributions of buildings, collectively for district or region. Issues would include green energy generation, water resource management, transportation, air emissions, habitat and ecosystems, and other larger scale issues.

Construction cost and energy savings discussions were usually presented in whole-building terms. The cost contribution of various building systems were distinguished in only one study. The majority of the initial cost increase was invested in energy-related building features.

Other benefits are acknowledged, although only one study presented them in monetary terms. This study indicated C&D waste reduction reduced construction cost by \$0.50/sq ft; GHG reduction was calculated to be

\$1.18/sq ft (net present value over 20 years, based on carbon value of \$5.00/ton); and occupant productivity increase was observed to be 1.5 percent, or \$998/yr/occupant, or \$36.89/sq ft.

Increased employee satisfaction is frequently attributed to improved IEQ, which in turn suggests reduced absenteeism, reduced employee turnover and increased productivity. While not quantified, the case studies show these benefits are indeed tangible and observable.

Applicability to the Army.

Literature about green building strongly suggests that significant energy and water savings are common benefits from designing and building to achieve a LEED rating. As new Army facilities are required to achieve a LEED Silver rating, similar savings should also be expected. Furthermore, the literature suggests that additional costs to achieve these savings are low; about a 2 percent increase in overall project cost. This amount is relatively insignificant in construction economics, especially at the budgeting phase. Therefore, the Army should expect to achieve these savings at a minimal additional cost. Several sources cite additional design effort accounts for some of this cost increase. As the architectural and engineering professions become more expert in green building and LEED practices, what is now seen as an additional design effort will become standard practice.

The literature also cited other benefits beyond energy and water savings. While a monetary amount may be difficult or impossible to calculate, it is still a tangible benefit that should not be underrepresented in decision-making. Meeting Federal mandates is critical to the Army, even if there is not a direct dollar-for-dollar payback.

Literature suggests that upgrading existing buildings to a green status (i.e., LEED-rated) is both practical and economical. As the Army's existing building inventory is far greater than its new construction programs, the Army should consider placing greater emphasis on upgrading existing buildings, and doing so in an environmentally responsible manner. Furthermore, using existing resources is the environmentally preferred option to disposing of existing resources and consuming new resources, even new "green" resources.

Unlike many commercial buildings that are constructed and owned on a short-term speculative basis, the Army owns and operates its buildings in

the long term. Therefore, reliance on lowest first cost and very short-term payback may not be in the Army's best interest. One must consider the impact of design, construction, operations & maintenance, and building function (i.e., process equipment, salaries) on the total life cycle cost of a building. An additional investment of about 2 percent in a building's environmental quality (reduced energy and water use, improved indoor environment) is negligible compared to the building's total life cycle cost.

No attention was paid to the environmental characteristics of building sites in the cited literature. As the Army owns and manages communities – small cities – the sustainability of the installation, community, and region are of a greater interest to the Army than to individual building owners. Site performance characteristics should not be ignored.

A business case for sustainable design in Federal facilities

The USDOE Energy Efficiency and Renewable Energy Laboratory (EERE) FEMP developed *The Business Case for Sustainable Design in Federal Facilities*. This document argues that facilities can be designed, constructed, and operated in an environmentally responsible manner, economically, within a Federal context. While not detailed analyses, the discussions of costs and benefits are well developed and supported.

Fifteen Federal case studies are included. The results echo the literature cited above. As the Federal government's interest in buildings is long-term, life cycle impacts are emphasized as well. Four examples are:

1. *Jones Federal Courthouse, Youngstown OH*. No initial cost data were given. Operational cost savings are estimated to be as follows, compared to baseline building performance.
 - Electrical energy: 10 percent savings
 - Heating energy: 22 percent savings
 - Total energy, annually: \$20,000.
2. *Zion National Park Visitors Center*. Construction and operating cost data were based on actual performance compared to baseline of conventional National Park building performance.
 - Construction cost: 30 percent savings compared to original design. Note that design revisions included a reduction in enclosed space
 - Energy: 70 percent savings
 - Electrical energy: 250,000 kWh savings annually
 - Annual savings: \$14,000.

3. *Navy Base Ventura CA, Building 850.* No initial construction cost was given. Operating cost savings are estimated compared to conventional construction.
 - Lighting: 64 percent savings
 - Plug loads: 46 percent savings
 - Heating: 67 percent savings
 - Cooling: 4 percent savings
 - Annual savings: \$20,000.
4. *Environmental Protection Laboratory, Research Triangle Park, NC.* Construction and operating cost data are based on actual performance compared to baseline of conventional building performance.
 - Construction cost: \$30 million savings compared to original design.
 - Energy: 40 percent savings
 - Annual savings: \$1,000,000.

In addition to direct economic benefits, *The Business Case* addresses indirect economic benefits to building owners and society; social benefits such as health and occupant comfort and well being, occupant satisfaction, and productivity; and environmental benefits such as reduced water and air pollutants, reduced GHG, reduced solid waste (SW), and conservation of natural resources and ecosystems.

The Business Case also makes the point that occupants' salaries and benefits constitute almost 90 percent of Federal buildings' total life cycle cost. Productivity, worker health, and absenteeism can suffer with poor IEQ, or can thrive with good IEQ.

4 A Process To Assess the Value of Green to the Army

General

A fundamental question motivating this work was to determine whether Army buildings designed and constructed with an explicit objective of reducing adverse environmental impacts (i.e., green buildings) are actually performing as intended, and do actually improve on buildings designed without any special environmental considerations. Another fundamental question is whether the Army is achieving value from the expenditures made for improved environmental performance in its green building initiatives.

A simplistic approach to these questions would be to compare green buildings' and baseline buildings' environmental performance, compare the performance levels, and then compare any cost difference or premium associated with the green buildings' performance. A cost/benefit type of assessment can then be made.

Unfortunately, neither measuring green performance nor assessing an economic cost or benefit to green performance is that simple. Measuring a building's green performance may be the more straightforward of the two requirements. Attributing cost to green performance is more challenging. A number of issues, discussed in the following paragraphs, must be considered when attempting to develop a performance measurement and cost/benefit or return-on-investment type of analysis.

Many elements of green performance are measurable in a quantifiable or observable manner, and are of direct interest to the Army.

Many elements of green performance are measurable, although the benefits may be more community or societal in nature; the Army may not pay directly, and would not be the direct recipient of the benefits.

Some elements of green performance can be measured at an individual building scale, although the real relevance is seen at a larger scale; an individual building's performance may not be entirely representative of the community or regional environmental performance.

Some elements of green performance cannot be measured. However, intuition or professional judgment can be applied to assess whether a design or construction feature is achieving some environmental benefit.

Attributing an economic cost to green performance is not always possible. Where green performance can be directly attributable to a distinct design or construction feature, the feature's cost can usually be determined. Where green performance is achieved through a combination of design or construction features, such as reduction in energy consumption, the cost contribution of each contributing feature may be indeterminable.

Attributing an economic value to some environmental benefits is not possible, at least within the context of conventional construction economics. Other analytical methods such as health risk assessment, disease avoidance, or mortality projections could possibly be applied, but would be unrealistic for this type of exercise. In these cases, a cost/benefit cannot be developed in purely monetary terms.

Realistically, not all building performance or cost data will be available or obtainable in the format or content to perform an all-inclusive cost/benefit or return-on-investment analysis. In the past, the Army did not have meters on buildings to measure electricity or natural gas. Each installation received one aggregate energy bill, which was not broken down by individual buildings. This changed with the Energy Policy Act of 2005, which required electric metering by 01 October 2012, and other advanced utility metering in Federal buildings by 01 October 2016. Contracted utility services do not always provide consumption data to the Directorate of Public Works, but the Army Metering Program was established to help installations measure and track usage at the facility level. A new Meter Data Management System is being established to receive meter readings from across the Army.* While the potential for analytical applications is huge, very few buildings are currently being metered to capture and analyze performance data.

EISA '07 requires that new facilities' energy and water consumption be monitored to verify compliance with its requirements. Energy

* More information on this metering program is available through URLs:
<http://www.Army.mil/-news/2009/08/31/26770-advanced-meters-developed-by-corps-of-engineers-help-Army-installations-reduce-energy-use-save-money/index.html>
http://www.usaasc.info/alt_online/article.cfm?iID=1007&aid=09

and water consumption data will be available, at least at the building level, but probably not the usage level, such as lighting or hot water heating.

A process to assess the value of green to the Army

Environmentally related performance can be measured in the Army's new green buildings, and costs for those buildings can be identified. Certain costs and economic benefit can also be determined based on available cost data or cost estimates. In that regard, a "cost of green" can be determined — the cost paid for the performance achieved. However, this information alone cannot reveal what value the Army is receiving. Value is relative, and a baseline must be established to identify differences in performance and cost between green and "standard" buildings.

The cost and performance comparisons described in this study are not intended to duplicate work planned to upgrade Army Standard Designs to improve their environmental performance under the Headquarters, U.S. Army Corps of Engineers (HQUSACE) funded project *Integration of Energy/Sustainable Practices into Standard Army MILCON Designs*. However, as these building types' performance are analyzed for opportunities to improve in-place performance, it would be beneficial to consider them as subjects for a "value of green" analysis:

- Battalion/Brigade Headquarters (Bn/Bde HQ)
- Unaccompanied Enlisted Personnel Housing (UEPH)
- Tactical Equipment Maintenance Facility (TEMF)
- Enlisted Personnel Dining Facility (EPDF)
- Company Operations Facility (COF).

These common Army facility types are found at most Army installations and represent a good mix of quarters-, administrative-, and operation-types of facilities. Furthermore, many of these buildings have been built within recent years, and are still being built. There should be ample opportunity to evaluate the performance of the newest, most sustainable buildings in the Army. New buildings to be monitored should be recently constructed, commissioned, then operated under normal conditions for four seasons. At least 1 full year of occupancy would be the minimum.

Standard buildings will form a baseline for comparison to green buildings. Baseline buildings must represent the "non-green" or "pre-green" condition. Their design should predate any deliberate, explicit intent toward sustainability, although it must be acknowledged these buildings were

designed to be as energy efficient as possible within technical and budget limitations of the time. In the Army context, achieving a SPiRiT Bronze level was mandated for all future Army buildings. These buildings were completed beginning Fiscal Year 2002. However, buildings that are so old to be functionally obsolete, especially in their envelope construction and mechanical and electrical systems no longer represent a “standard” building design and performance. Buildings designed between the mid 1990s and 2002, therefore, should be suitable candidates. As the building types being studied for *Integration of Energy/Sustainable Practices into Standard Army MILCON Designs* are common facility types, most major Army installations should have these buildings on-site.

Baseline building and green building comparisons should be of the same general building type within the same climatic conditions. Comparing buildings on the same installation is the preference. Buildings should also be of similar occupancy and activity patterns. While they need not be identical, buildings should be as similar as possible in occupancy and activity patterns. Performance should be compared on a building-to-building basis. However, a valid comparison can also be made on a unit basis (per person, per square foot, or similar service unit) if the buildings’ scopes are significantly different.

Assessing improved environmental performance and any costs associated with green performance will require in-place monitoring of baseline and their counterpart green buildings concurrently. Monitoring all five building types at one installation is not necessarily a requirement, but may be the most practical approach. Installing meters, reading meters, performing on-site performance tests, and other monitoring tasks may be best conducted at the same installation (if for no other reason than to conserve the evaluators’ travel resources). Ideally, facilities should be monitored at multiple installations, preferable representing a range of climatic conditions. However, as a minimum, monitoring buildings at one installation should still reveal useful results.

Anecdotal evidence suggests Public Works personnel at Army installations will be unable to perform monitoring tasks on behalf of the study team. Therefore, the study team should itself be prepared to install meters and perform monitoring activities without significant assistance from the Directorate of Public Works.

Many characteristics of green performance will have a direct cost impact to the Army, and a direct economic benefit. Operational expenses of baseline and green buildings should be obtainable as they are incurred. However, acquiring construction and past operation or maintenance costs will be a challenge. New building construction cost data should be available from the USACE district. However, it is unlikely this data will enable the cost of sustainability-related building features to be determined in all cases. Cost estimates will have to suffice in some cases. Construction costs for the sustainability-related features of the baseline buildings and components will have to be estimated. Costs incurred for both baseline and green buildings should be normalized to present value at the time of the study.

The green performance characteristics for which a monetary cost or a monetary benefit cannot be calculated can still be compared. The difference in performance levels or values will have to stand by themselves.

In any case, assessing the value of green buildings to the Army must consider both a monetary element and an environmental performance element.

An outline for a building performance and cost measuring protocol

There are two sources of note that may help useful to developing an Army green building performance-and-cost evaluation.

The LEED Energy and Atmosphere Credit 5 (EA 5), “Measurement and Verification,” provides guidance on developing a process for longer-term monitoring and verification of a building’s performance. The LEED guidance essentially references the International Performance Measurement and Validation Protocol (IPMVP) publications, which include energy, water, and renewable energy sources. While the IPMVP guidance may be quite useful for measuring performance of these selected characteristics, it would not be applicable in and of itself for measuring the whole spectrum of green performance characteristics. Furthermore, the IPMVP processes do not address costs for achieving the measured performance.

The U.S. Department of Energy, PNNL’s *Building Cost and Performance Metrics: Data Collection Protocol* describes a broader perspective on a green building performance. While its organization is not identical to that of green performance attributes described in Chapter 1, it is similar in many respects.

The recommended performance and cost measurement protocol was developed by compiling relevant environment characteristics or attributes described in Chapter 1. For each attribute, an assessment was made to indicate the following.

- Whether performance could be measured
- Whether there was a potential additional cost to the Army to achieve an improved environmental performance
- Whether there was a potential monetary benefit to the Army
- Whether there were any other non-monetary benefits to the Army
- Whether a monetary cost/benefit or return-on-investment type of analysis was possible
- Whether a monetary cost/benefit or return-on-investment type of analysis was practical for the purposes of this White paper
- Whether measurement of performance and cost should be included in this White Paper
- Where performance and cost cannot be measured, whether it is useful to address this performance in another, more qualitative manner.

To assess the performance of both baseline buildings and green buildings and the costs associated with green performance, the characteristics discussed in the following paragraphs should be monitored; the discussion includes the characteristic to be measured, a general description of the metrics that can be applied, costs to the Army, economic benefit to the Army, and other non-monetary environmental performance that should be measured.

Project innovation

“Project Innovation” is not a building performance characteristic or attribute per se. However, application of various techniques and practices throughout the project development process can improve the green performance of the building through its service life. Furthermore, LEED acknowledges Project Innovation in its credit structure.

The following characteristics should be assessed:

Facility Commissioning: While commissioning itself is not a design or construction feature, it does suggest the facility’s mechanical and electrical systems should operate more efficiently and economically. The metric for this characteristic is whether commissioning was or was not performed on the facilities’ completion. The cost to the Army would be the cost of the commissioning exercise. The

economic benefit is the increased efficiency of the facilities' operating systems (comparing comparable baseline and green building types) in whole building energy use and resulting energy cost reduction.

LEED Measurement and Verification Credit: While developing an M&V plan does not in and of affect green performance, it does suggest the facility's energy and water systems will be monitored and adjusted to operate more efficiently and economically over the facility's service life. The metric for this characteristic is: (1) whether an M&V plan was (or was not) developed for the facilities, and (2) whether the M&V plan is being executed. The cost to the Army would be the cost of the developing and executing the M&V plan. The economic benefit is the increased efficiency of the facilities' operating systems (comparing comparable baseline and green building types) in whole building energy use and resulting energy cost reduction.

Facility Management/Occupant Training: Training is not a building performance metric per se. However, presence or absence of training does indicate whether the intent of the design to achieve environmental performance is likely or unlikely to be maintained throughout the building's service life. The metric will be whether Public Works personnel and the buildings' tenants are or are not being trained throughout the building's service life to preserve its environmentally related performance characteristics.

Land/site

The environmental benefits of sustainable project sites are seen more at the development, community or regional level than at the individual site. Economic costs can be measured at the project site level. Economic benefits can occur at a broader scale, although some benefits may be difficult to quantify in monetary terms. The following performance characteristics should be evaluated.

Area of Disturbed Site: Limiting the area of the site that is disturbed during construction activities, reduces requirements for dust abatement, erosion and sedimentation control, grading, and site planting. The metric for this characteristic is the area of site (square feet or acres) disturbed during construction. This metric will accrue no cost to the Army. The economic benefit of reduced mitigation measures will accrue to the contractor, and will be impractical to calculate or estimate. The environmental benefits will be impractic-

al to quantify, although they should include reduction in water for dust suppression, reduction of watering vehicle fuel consumption and emissions, reduction of grading equipment fuel consumption and emissions, and reduced use of water and fertilizers for new seeding and site restoration. Note that, if this information is not available for the baseline building, an assumption should be made that 100 percent of the available site was disturbed during construction.

Material Source and Disposal: If existing site materials (soil, rubble, landscape materials, etc.) are used on site, the requirement for materials to be brought onto or removed from the site during construction will be reduced, as will the transportation burden for materials hauling. The metric for this characteristic is the quantity of site materials (cubic yards or tons). This metric will accrue no cost to the Army; in fact, it should lower construction cost compared to the baseline buildings. The economic benefit of reduced materials handling will be a slightly lower construction cost. The environmental benefits will be impractical to quantify, although they should include reduced vehicle fuel consumption, emissions, and dust generation. Note that, if this information is not available for the baseline building, an estimate will have to be made of land clearing and inert debris (LCID), and borrow and spoil based on recent similar construction projects.

Area of Paving/Impervious Surface: If a smaller area of the site is covered with impervious paving, less paving material is produced and consumed, less storm water runoff is generated and less runoff is contaminated by paving surface pollutants. The metric for this characteristic is the area of site (square feet or acres) covered with impervious paving. This metric will accrue no cost to the Army; in fact, it should lower construction cost compared to the baseline buildings. The economic benefit of reduced paving will be a slightly lower construction cost. The environmental benefits will be impractical to quantify, although they should include reduced life cycle environmental impacts associated with producing and placing paving materials (cement, in particular), reduced quantity of storm water runoff to collect and discharge, and reduced contamination of storm water runoff. A future benefit is that there will also be less waste when the facility is eventually removed and redeveloped.

Landscape Maintenance: Developing low maintenance landscape designs can reduce ongoing resource consumption and waste. Me-

metrics are: (1) volume of irrigation water over the measurement period, (2) quantity of landscape waste materials (by volume or weight), and (3) quantity of chemicals (pesticides and fertilizers) applied during the measurement period (tons of dry material or gallons of liquid materials). The cost to the Army would be the difference in construction costs between xeriscape or other low maintenance vegetative landscaping and conventional turf grass installed at the baseline sites. The economic benefit to the Army would be the savings in the cost of potable water used for irrigation, of mowing, and of landscape chemicals. Additional environmental benefits would include an estimated reduction of emissions from lawn mowing equipment, based on operating hours.

Storm Water Management: Reducing the quantity of storm water runoff discharged from the site will lessen the burden on the installation's storm water drainage infrastructure, lower the potential for flood and erosion damage downstream from the site, and lessen the potential for contaminants to be carried into surface water courses. The metrics for this characteristic are: (1) the volume and rate of runoff leaving the site and (2) concentration of contaminants in storm water runoff water (petroleum products, pesticides from landscaped areas, suspended solids). Runoff calculations are described in the LEED Reference Guide. Runoff quality can be determined through water sampling downstream of a building site. The cost to the Army would be the construction cost of storm water management features such as bioswales, pervious pavement, retention basins, rain gardens or wetlands, compared to the storm water management features of the baseline sites. The economic benefit to the Army may be difficult to quantify, especially on a building-by-building basis. However, reductions of flooding, erosion damage, flash flooding, or surface water pollutants are tangible environmental benefits that should be documented.

Beneficial Use of Storm Water. Beneficial uses of storm water can reduce the use of potable water for irrigation and other uses for which non-potable water is appropriate. The metric for this characteristic is the volume of storm water used for beneficial purposes during the measurement period. The cost to the Army would be the construction cost of storm water conveyance and retention features from which the water can be drawn, assuming the baseline sites do not include similar features. The economic benefit to the Army

would be the cost avoidance of not using the measured quantity of potable water.

Heat Island Management: The heat island effect has no direct, immediate impact on the Army per se, although it is recognized in LEED and other sources as a characteristic relevant to green building. The metric is the solar reflectance index (SRI) of the total hard surface area of the site, calculations for which are described in the LEED Reference Guide. The cost to the Army would be the installation of features to reduce the total reflectance, such as substitutes for hard surfaces and shading devices compared to similar features of the baseline buildings. The economic benefit would be a reduced cost of cooling the building. However, isolating the impact on cooling energy cost attributable to this single feature would require energy modeling (rather than direct measurement). Other environmental benefits include a reduction of artificial changes to the local microclimate.

Water

Water consumption is measurable and has a direct cost impact to the Army. The following performance characteristics should be evaluated.

Potable Water Consumption: The metric for this characteristic is the volume of potable water consumed in the building during the measurement period. Measurement will require metering. Metering of building water use is required by EISA 2007. There will be practical limits to the information obtained through metering. If one meter measures consumption at the domestic supply entrance to the buildings, only whole-building consumption data will be available. Consumption by showers, toilets, process equipment or fixtures, and other uses cannot be distinguished. It may be practical to meter interior and exterior water consumption separately. Branches could conceivably be metered independently, although each branch is more likely to supply fixture groups by location, not necessarily by function or fixture type. When comparing a baseline building's and green building's water consumption, the occupancy and activity patterns must be the same for both buildings, otherwise the comparison will not be valid. The USGBC LEED EA 5, "Measurement and Verification," provides guidance on developing a process for longer-term monitoring and verification of a building's water use performance, and in turn references the IPMVP. The cost to the Army will be the cost of water conserving fixtures compared to

standard, non-conservation fixtures. The economic benefit to the Army will be the cost savings from reduced water use. Additional regional benefits can be evaluated, depending on the location. These may include reducing the demand on a declining potable water supply, reducing the likelihood of aquifer contamination, or responding to regulatory mandates. Reducing water use will also help the Army meet Federal and DoD water use reduction mandates. Other benefits include reduced energy to treat and pump water and resulting sewage, and reduced energy to heat hot water. Tools such as the USEPA's WATERGY (software) can be used to calculate savings due to nine water conservation best management practices (BMPs). WATERGY uses local rates for water, sewage treatment, and energy. Additional benefits include alleviating stress on water infrastructure by reducing water volumes and regulatory mandates and incentives, such as water rate and tax subsidies. In regions where water is scarce, conservation ensures sustainability of supply. Alternative sources (e.g., desalination, long-distance pumping) can be very expensive.

Sanitary Treatment: Reducing water use also reduces the amount of water that must be conveyed to a sanitary treatment facility. The metric for this characteristic is the volume of water consumed in the building during the measuring period (see above), which in turn will be treated by a sanitary facility. The cost to the Army will be any premium paid for water conserving fixtures, as compared to standard, non-conservation fixtures. The economic benefit to the Army will be the cost savings from a reduced sanitary waste volume. An additional environmental benefit will be that reducing the demand on sanitary treatment facilities will free some capacity, which can help prevent sanitary system overflow in the event of heavy rainfall or flooding. An economic benefit, however, will be difficult to quantify in monetary terms unless recent overflow damage and clean-up cost data were available.

Innovative Use of Waste Water: Gray water or bioremediation systems (or "living systems") may still be rare on Army installations. However, they should still be evaluated for water use reduction where they occur. The metric for this characteristic is the volume of wastewater that is treated and used in lieu of potable water. This can be metered. The cost to the Army is the cost of the bioremediation facility's or gray water capture system's construction. The economic benefit to the Army will be cost savings accrued from the re-

duction of wastewater treated by conventional treatment facilities, and the reduction of potable water that would have been used if gray water or waste water were not available.

Building energy

Consumption of electrical, natural gas, fuel oil, and other energy sources are measurable, have a direct cost to the Army and have direct economic benefits to the Army. The following performance characteristics should be evaluated.

Heating, Ventilation, Air Conditioning and Domestic Hot Water Energy Use: The metric is the amount of electricity, natural gas, fuel oil, and other energy sources (kWh electricity, MBtu for the other sources) consumed by the building for thermal comfort and domestic hot water during the measurement period. Each source can be metered separately. It is recommended that domestic water heating sources be metered separately from the remainder of the building to distinguish between hot water use and other heating requirements. This is especially useful for facilities that have a high domestic hot water demand, such as barracks. It is also recommended that chillers and the remainder of the building be metered separately to distinguish between cooling and other electric power requirements. The USGBC LEED credit EA 5, "Measurement and Verification," provides guidance on developing a process for longer-term monitoring and verification of a building's energy performance, and in turn references the IPMVP. The cost to the Army would include the cost of the green buildings' energy conservation-related features of the building envelope, heating equipment and distribution, cooling equipment and distribution, and energy management control systems (EMCS) compared to those of the baseline buildings. The cost of energy modeling conducted during design should also be included. The economic benefit to the Army would be the cost savings from consuming less electricity, natural gas, fuel oil, and other fuel sources. In addition to the environmental benefit associated with energy use reduction, reducing energy consumption will also help the Army meet Federal and DoD energy reduction mandates.

Lighting Energy Use: The metric is the amount of electricity consumed for lighting during the measurement period. Ideally, lighting circuits should be metered independently. The cost to the Army would be the cost of the green buildings' lighting fixtures, distribu-

tion, and any lighting controls systems compared to those of the baseline buildings. The economic benefit would be the reduced cost due to reduced energy consumption from higher efficiency luminaires, daylighting, and lighting management controls. In addition to the environmental benefit associated with energy reduction, reducing energy use by lighting will also help the Army meet Federal and DoD energy reduction mandates. Alternatively, actual daylighting performance can be measured at the baseline buildings and green buildings. One metric can be the difference in footcandles at the prescribed surface. Another metric can be the calculation of the visible light transmittance (VLT) and window-to-floor area ratio (WFR). Measurement methods are described in the LEED reference guide under IEQ credit 8.1. The difference in lighting costs between the baseline and green buildings would have to be calculated based on lighting design modeling to represent the actual daylight illumination measured, and the artificial lighting required to achieve the appropriate illumination level.

Alternative Energy Sources: While not common on Army buildings, alternative energy sources should be monitored where they appear. The metric is the electrical energy generated by photovoltaics or wind turbines (kWh), or the thermal energy generated by solar collectors (MBtu). Cost to the Army would be the cost of these systems in the green buildings, assuming no such systems were installed in the baseline buildings. The economic benefit would be the cost savings attributed to the reduced use of electricity, natural gas, fuel oil, or other fuels. In addition to the environmental benefit associated with alternative and renewable energy sources, using alternative energy sources will also help the Army meet Federal and DoD renewable energy mandates.

Light Pollution: Light pollution occurs when exterior lighting exceeds the illumination necessary for functional and safety purposes, such that it is directed to areas (the sky, off the building site, into other buildings) where it is not intended or necessary. The metrics are (1) exterior lighting does or does not conform to illuminated areas and power density per American Society of Heating, Refrigerating, and Air-Conditioning Engineers [ASHRAE] 90.1, and (2) the horizontal and vertical footcandles at the site boundary are limited per the Lighting Zone classification. Calculations are described in the LEED reference guide under SS credit 8. The cost to the Army would be the cost of exterior light fixtures for the green building

(International Dark Sky Association approved) compared to those of the baseline buildings. The primary benefit of reducing light pollution is environmental; less light is directed/reflected skyward. However economic benefits can be measured if exterior lighting can be metered separately. If so, electrical energy can be monitored and the costs compared.

Air and atmosphere

Air quality and atmospheric impacts are generally applied to the regional or global level, as opposed to a building level. However, since buildings contribute relatively large quantities of emissions and environmental stressors, each building's performance should be measured as a contributor. The following performance characteristics should be evaluated.

Carbon/Greenhouse Gas Emissions: Buildings' energy consumption and savings are discussed above. In addition to the economic benefits of reducing energy consumption, reducing carbon and GHG emissions will also result. Given an energy savings, the GHG reduction can be calculated with USEPA's *Emissions & Generation Resource Integrated Database (eGRID)* program. The metric is reduction of CO₂E and GHG emissions (tons, or metric tons of each compound) due to reduced consumption of each energy source. In addition to the environmental benefit associated with carbon and GHG reduction, reducing carbon/GHG emissions will also help the Army meet Federal and DoD emission reduction mandates.

Dust and Particulate Emissions: Construction activities generate dust and particulates that are released into the air. If not controlled, they can become a nuisance (PM₁₀ or larger) or even a health hazard (PM_{2.5} and smaller). Standard USACE construction contract provisions address dust suppression during construction, but do not establish thresholds or require monitoring. Therefore neither baseline building nor green building projects will have had any measurements of dust released during construction. However, measuring particulate emissions for the occupied buildings and new construction sites should be considered in the future. The metric would be concentration of dust (dust density, optical density, or opacity) at the site perimeter, according to an accepted monitoring protocol. Benefits would be essentially environmental. Assessing a monitoring value to reducing particulate emissions will be difficult.

Vehicle Emissions: Emissions from vehicles and equipment will occur primarily during construction activities. Standard USACE

construction contract provisions do not address off road construction equipment emissions. Therefore neither baseline building nor green building projects will have had any measurements of vehicle emissions during construction. However, monitoring vehicle emissions for new construction projects should be considered in the future. (It is becoming more common in European Union countries.) The metric would be concentration of CO₂, NOX, CO, hydrocarbons (HC) and other emissions of concern. Emissions can be tested on the vehicles with a portable emissions measurement system (PEMS). Benefits would be essentially environmental. Assessing a monetary value to reducing vehicle emissions will be difficult.

Indoor environmental quality

Many characteristics of the indoor environment can be measured. IEQ affects the occupants, their health, and their productivity. The costs of maintaining a high environmental quality and benefits to occupants are often difficult to calculate in monetary terms. Multiple building features (finish materials selection, air change rate, and others) contribute to indoor air quality. It is difficult to isolate the contribution of each. Benefits to the occupants (e.g., morale, comfort, health, and productivity) are tangible, but extremely difficult to measure in strictly monetary terms. The following performance characteristics should be evaluated.

Indoor Air Quality Management Plan: An “IAQ Management Plan” is not a building performance characteristic or attribute per se. However, the development and diligent application of IAQ management practices throughout a building’s design and occupancy phases improve the green performance of the building through its service life. As its occupants constitute the greatest expenditure throughout a building’s life, it is worthwhile to evaluate their response to the interior environment. The metrics would be: (1) whether an IAQ management plan has or has not been developed, and (2) whether it is or is not actively applied to each the baseline and the green buildings. Practices described in LEED IEQ credits 1-5 and 10 may be included in an IAQ plan, and will apply throughout a building’s life. The cost to the Army would be the development of the IAQ Management Plan. Costs will also be incurred throughout its application (evaluation of materials and products brought into the building, evaluation of ventilation rates), although these costs may be very difficult to accurately record. The economic benefits will not be directly applicable to the existence of the plan

itself, but to the resulting indoor air quality achieved by its application.

Indoor Air Quality: LEED includes two prerequisites and 10 credits related to indoor air quality. They address source materials, controls during construction and prior to occupancy, controls during occupancy, and ventilation. Ultimately, the quality of indoor air is measured by the presence and concentration of pollutants through the building's life. The metrics for measuring IAQ are the concentrations of each of several pollutants (milligram or microgram per cubic meter of air). Monitoring is recommended for: formaldehyde, Total Volatile Organic Compounds (TVOC), Carbon monoxide, carbon dioxide, particulates (PM_{2.5} equivalent mass) and air change rate (air changes per hour). Assessing a cost to the Army to reduce these concentrations is not practical, as so many variables contribute. Assessing the benefits in monetary terms is not practical. However, monitoring is still recommended to validate practices such as material and source control and ventilation are, indeed, achieving the desired IAQ.

Occupant Satisfaction: Occupant satisfaction is an indirect measurement of the quality of indoor environments. A building's occupants' satisfaction and comfortable in their workplace or residence contribute to their health and productivity. Several occupant surveys have been developed for assessing IEQ, including the U.S. General Services Administration, Carnegie Mellon University, and the USDOE's PNNL. The metric would be the baseline and green building survey results according to the selected survey instrument. The cost to the Army to achieve a higher occupant survey score will be impractical to document, as would an economic benefit to the Army.

Materials and resources

Responsible use of materials and resources is measurable and has a direct cost impact to the Army. There are some direct economic benefits to the Army (reduced disposal costs). There also tangible benefits that are more global in impact, but have no direct monetary benefit to the Army (reduced GHG emissions). The following performance characteristics should be evaluated.

Construction and Demolition Waste Reduction: The metric is the C&D diversion achieved during construction (weight or volume). This information should be available for green buildings through

LEED credit MR 3 submittals. As this performance will not have been recorded for baseline buildings, assume the rate for them is zero. There should be no cost to the Army. Economic benefits to the Army would be the reduced cost of landfill disposal, including hauling and tipping. Assume the prevailing commercial tipping fees. Benefits also include the reduced life cycle environmental impacts associated with recycling. These can be calculated using Life Cycle Assessment software such as the Athena Environmental Estimator for Buildings. A short-term measurement of green performance will not include subsequent remodeling or upgrading activities.

Use of Used, Recycled, or Rapidly Renewable Materials: The metrics are: (1) the quantity of used and recycled materials incorporated into the new construction (by weight) and (2) quantity of rapidly renewable materials incorporated into the new construction (by percent of dollar value). This information should be available for green buildings through LEED credit MR 4 submittals.

As this performance will not have been recorded for baseline buildings, assume the rate for them is zero. Cost to the Army would be the difference in cost between the recycled content materials and similar virgin and non-renewable materials. Benefits also include the reduced life cycle environmental impacts associated with recycling materials and using rapidly renewable materials. These can be calculated using Life Cycle Assessment software such as the *Athena® Impact Estimator for Buildings*.^{*} A short-term measurement of green performance will not include subsequent remodeling or upgrading activities.

^{*} <http://www.athenasmi.org/tools/impactEstimator/index.html>

5 Summary and Recommendations

Summary

“Green” may be measured in direct economic terms, non-economic units of measure, or other non-quantitative terms. Energy and water consumption can be measured and the costs of consumption can be calculated. Many elements of green performance are measurable, such as green house gas emissions, although not in direct economic terms. Benefits may be more community or societal in nature; the Army may not pay directly, nor would be the direct recipient of the benefits. Some elements of green performance cannot be measured. However, intuition or professional judgment can be applied to assess whether a design or construction feature is achieving some environmental benefit.

Numerous definitions of “green buildings” have been published. They essentially refer to reducing the adverse impacts of buildings on the built environment. The USGBC’s LEED rating system has become a de facto green building definition of sorts, describing properties in areas of sustainable sites, water efficiency, energy and atmosphere, materials and resources, and IEQ. While LEED is a rating system, not a definition or design guidance per se, it provides a good working context for discussions of green building cost and performance.

For the purposes of this work, costs, benefits, and performance were discussed in the context of green (also described as “LEED-rated”) buildings, as compared to conventionally designed and constructed (i.e., “non-LEED-rated”) buildings.

The discussion of measuring green building performance follows a similar context to the LEED rating system, although not identical. The major areas of measurement are: (1) Land/Site, (2) Water, (3) Building Energy, (4) Air and Atmosphere, (5) IEQ, and (6) Materials and Resources. A seventh category of Project Innovation is included as well, to evaluate some of the practices that will support successful green building design, construction, and occupancy. Project Innovation is a category in the LEED rating system as well. These descriptions were developed based on several organizations’ descriptions of green building attributes, as well as compatibility with in-place performance monitoring and measurement.

This work has also cited and discussed 20 green building case studies; more case studies have been referenced in Appendix B to this report. These case studies specifically address design and construction costs, building performance, and economic benefits. Virtually all the case study analyses cite an increase in project cost associated with green (i.e., LEED-rated) building. Studies that described green buildings simply as “green” or “LEED-rated” indicated a cost increase ranging from 1 – 6.8 percent, with a “typical” cost increase of about 2 percent. Studies that distinguished among the LEED levels indicated the following cost increases:

- Certified: 0 – 15 percent; a “typical” increase is about 2 percent
- Silver: 0 – 13.5 percent; a “typical” increase is about 3 percent
- Gold: 0.5 – 15.8 percent; a “typical” increase is about 6 – 7 percent
- Platinum: 4.6 – 22.2 percent, a “typical” increase is about 8 percent.

Two studies about retrofitting existing buildings suggest achieving LEED-EB ratings can be accomplished at a lower additional cost than for new construction, i.e., less than 1 percent (\$2.00/sq ft) additional cost.

These sources all reflect that green buildings (specifically LEED-rated buildings) exceed the performance of standard buildings (i.e., non-LEED buildings), most to a significant degree. The performance measured, at least in monetary terms, is typically energy and water consumption, i.e., the savings resulting from reduced consumption. Virtually all the case study analyses comparing green and non-green buildings reveal that green buildings perform better than non-green buildings. The metric for this evaluation almost always includes energy and water use savings, both in modeled performance and in actual measured performance. The literature indicates the following savings:

- Energy savings: 16 – 33 percent, with a “typical” energy savings of about 30 percent
- Water savings: consistently over 30 percent.

There are, however, cases where green buildings do not perform as well as standard buildings in these areas.

The literature also describes other benefits, although rarely in monetary terms. These include reduction of GHGs, reduced pollutants, and occupant satisfaction. Only one study presented these benefits in monetary terms:

- C&D waste reduction savings: \$0.50/sq ft
- GHG reduction savings: \$1.18/sq ft (net present value over 20 years, based on carbon value of \$5.00/ton)
- Occupant productivity increase: 1.5 percent, or \$998/yr/occupant, or \$36.89/sq ft.

While the USDOE's *The Business Case for Sustainable Design in Federal Facilities* does not provide the level of analysis envisioned in this document for monitoring and measuring performance in Army buildings, it does include another 15 case studies of Federal buildings, and provide well developed and supported arguments that green buildings can be designed and constructed economically, and achieve high levels of green performance.

This work has identified candidate building types for monitoring and measurement. Army Standard Designs for these building types exist and will be evaluated for potential improvements to their environmental performance. Existing buildings of these types, roughly 8 to 15 years old, should be present on most Army installations. These will serve as "baseline" buildings. As recent and upcoming MILCON programs included these buildings, examples of new, green buildings should also be present. Comparisons of similar building types on the same installation is the preferred approach.

This work also developed an outline for a green building monitoring and measurement protocol (drawn to some extent from the USDOE's *Business Case*) that follows the description of green building characteristics discussed above. This protocol describes:

- specific meaningful and practical characteristics to be measured
- measurement requirements and methods
- economic costs involved in design and construction, and economic benefits involved with payback
- other environmental benefits that are impractical to measure in monetary terms.

While this protocol may not yet be sufficiently developed to apply directly to a performance monitoring task, it should provide a good definition of scope and form a good foundation for further development.

Recommendations

It is recommended that this document be considered required reading for all within the Army involved in facilities planning, construction, and management. This work reinforces the concept of sustainability as an holistic, long-term endeavor that must be maintained at the facility, installation, and community scales.

Sustainability performance must be accommodated in planning and budgeting, at least at the building complex scale, and ideally at the program scale (a responsibility of the Assistant Chief of Staff for Installation Management [ACSIM]). Sustainability criteria must be incorporated into facilities' designs (new and existing building renovation) and verified throughout the facility delivery process ensuring that facilities meet users' requirements (a USACE's responsibility). Sustainability performance must be maintained throughout facilities' service lives (an Installation Management Command [IMCOM] responsibility).

In general, the studies cited in this document agree that, although some additional implementation cost to achieve "green" performance (i.e., a LEED rating) is necessary, green building performance is significantly improved over non-green building performance. However, identifying a single whole-building cost or performance does not provide sufficient information to develop designs and manage facilities to optimize design, performance, and life cycle economies for the Army.

Therefore, it is recommended that the Army conduct an integrated study of new facilities to assess the performance in energy reduction, water conservation, GHG reduction, storm water management, occupant health and safety, and other environmental issues of concern. The Engineer Research and Development Center, Construction Engineering Research Laboratory (ERDC-CERL) is currently participating in an HQUACE-funded project to identify the increased cost necessary to upgrade five Army Standard Designs to incorporate all requirements that are mandated through Federal, DoD, Army and/or USACE directives that are related to the reduction of energy and water consumption. Several demonstration projects will be planned, bid, and constructed to learn how effectively the energy and sustainability enhancements achieve the predicted savings,

and at what increase in construction cost. These buildings would be the best candidates for monitoring to ensure the requirements are met with the facilities in-place. ACSIM, USACE, and IMCOM should invest in this study, either monetarily or with services in-kind to take advantage of lessons learned for all future new construction. Other metrics such as IEQ, air and water emissions, resource use and waste reduction, and other non-energy, non-water environmental performance characteristics could be studied during these demonstration projects.

The most common facility types will be the most useful to monitor. These facility types are being, and will be constructed in the greatest numbers throughout the Army. Chapter 3 describes candidate facility types, although others could be feasible as well. Facilities should be newly constructed, and should have been in operation for approximately 1 year. A monitoring period of at least 1 year is recommended to assess performance over all seasons. Monitoring over a longer period of time is recommended.

“Pre-green” or “early green” buildings should also be monitored to establish benchmarks in cost and performance, and the benefits realized with the Army’s green building practices. Benchmark buildings should be of the same facility type and as close as possible in occupancy and operation to the new buildings being monitored, and should be approximately 8 to 12 years old. As the suggested facility types are common, both new and benchmark buildings should be present at most installations. New and benchmark facilities should ideally be located at the same installation.

Monitoring should include cost and performance during the design, construction, and occupancy phases. Elements of performance may include, but need not be limited to, estimated or modeled performance, actual performance, design and construction costs, operating costs (including utilities), IEQ, carbon emissions, storm water management, and other performance measures relevant to the Army.

It is important to “monitor intelligently.” That is, to integrate performance monitoring plans into facilities’ designs. This will enable evaluators to identify performance at the most useful levels of analysis. For example, lighting systems should be on independent circuits from other electrical power distribution so actual lighting performance can be monitored. Similarly, different potable water uses should be serviced by independent branches so actual water consumption for each use can be monitored. Process-related electrical circuits and water branches should be indepen-

dent to enable monitoring of process loads. Simply installing meters at the buildings' electrical or water service entrances will not provide the required level of detail.

It is important to capture data as they are generated. This includes design analyses, performance modeling (especially energy and building envelope performance), water consumption simulations, design costs, construction costs, utilities consumption and costs, and other features of buildings' occupancy and operation.

The buildings to be monitored should be enhanced-commissioned. The Army can also use this activity to establish reasonable process loads for the facility types.

In addition to reporting on Army green buildings' performance, the products of this evaluation should include:

- An M&V protocol for Army facilities that is realistic for the Army to perform, and will provide the information necessary to improve future design, construction, and operation of Army facilities.
- Verification that new Army buildings are complying with the EISA and other mandated requirements for energy.
- Promotion of best practices for Army green building design, construction, commissioning, and management. Best Practices can be endorsed by command memorandum and policy. They can be institutionalizing through USACE training programs, IMCOM's Installation Management Institute, and similar Army training and continuing education programs. Participating in industry continuing education and training, such as USGBC curricula, among others, will also help indoctrinate facility design, construction, and management personnel.

This document has discussed the performance of new buildings. However, the potential for achieving green performance in existing buildings must also be acknowledged. The case studies cited in this report suggest that existing buildings can be retrofitted to achieve a "green" building performance at a modest cost, and many features can be implemented at little or no additional cost. The Army has invested considerable effort and funding into energy conserving upgrades in existing facilities. However, most attention has been devoted to "energy" as opposed to "sustainability" in a more holistic context. It is therefore recommended that the Army recognize the potential for achieving green performance in the vast majority of its buildings.

Acronyms and Abbreviations

<u>Term</u>	<u>Spellout</u>
ACEEE	American Council for an Energy-Efficient Economy
ACSIM	Assistant Chief of Staff for Installation Management
AE	Activities and Events
ANSI	American National Standards Institute
AP	Accredited Professional
ASHRAE	American Society of Heating, Refrigerating, and Air-Conditioning Engineers
ASTM	American Society for Testing and Materials
BIM	Building Information Model
BMP	Best Management Practice
BOMA	Building Owners and Managers Association International
CASI	Center for the Advancement of Sustainability Innovations
CBE	Center for the Built Environment
CEERD	U.S. Army Corps of Engineers, Engineer Research and Development Center
CERL	Construction Engineering Research Laboratory
CFR	Code of the Federal Regulations
CO	Carbon Monoxide
COBRA	Comprehensive Omnibus Budget Reconciliation Act
COF	Company Operations Facility
CRT	Cathode Ray Tube [video monitor]
CW	Civil Works
DASA(I&H)	Deputy Assistant Secretary of the Army, Installations and Housing
DC	District of Columbia
DOE	U.S. Department of Energy
EA	Energy and Atmosphere
EB	Existing Building
EERE	[U.S. DOE] Energy Efficiency and Renewable Energy
EISA	U.S. Energy Independence and Security Act of 2007
EMCS	Energy Management Control System
EMS	Energy Management System
EO	Executive Order
EPA	Environmental Protection Agency
EPACT	Energy Policy Act of 2005
EPCA	Energy Policy and Conservation Act
EPDF	Enlisted Personnel Dining Facility
EPP	Environmentally Preferable Purchasing
ERDC	Engineer Research and Development Center
ETS	Environmental Tobacco Smoke
EUI	Energy Use Intensity

<u>Term</u>	<u>Spellout</u>
FEMIA	Federal Energy Management Improvement Act
FEMP	Federal Energy Management Program
FUDS	Formerly Used Defense Sites
FY	Fiscal Year
GBCI	Green Building Certification Institute
GHG	Greenhouse Gas
GJ	Giga joules
GSA	General Services Administration
HC	hydrocarbons
HQ	Headquarters
HQUSACE	Headquarters, U.S. Army Corps of Engineers
HVAC	Heating, Ventilating, and Air-Conditioning
HW	Hazardous waste
IAQ	Indoor Air Quality
IEQ	Indoor Environmental Quality
IFMA	International Facility Management Association
IHS	Indian Health Service
IMCOM	Installation Management Command
IPMVP	International Performance Measurement and Validation Protocol
ISP	Installation Sustainability Plans
IUCN	International Union for Conservation of Nature and Natural Resources
LCC	Life Cycle Cost
LCCA	Life-Cycle Cost Analysis
LCD	Liquid Crystal Display
LCID	Land Clearing and Inert Debris
LEED	Leadership in Energy and Environmental Design
MEP	Mechanical/Electrical/Plumbing
MILCON	Military Construction
NC	New Construction
NECPA	National Energy Conservation Policy Act
NG	National Guard
NOX	Nitrogen Oxide
NPS	National Park Service
NSN	National Supply Number
OACSIM	Office of the Assistant Chief of Staff for Installation Management
ODS	Ozone-Depleting Substance
OMB	Office of Management and Budget
OSD	Office of the Secretary of Defense
PBS	Public Building Service
PEMS	Portable Emissions Measurement System
PNNL	Pacific Northwest National Laboratory
PO	Post Office

<u>Term</u>	<u>Spellout</u>
PV	Photovoltaic
RCRA	Resource Conservation and Recovery Act
RFP	Request for Proposal
ROI	Return on Investment
ROR	Rate of Return
SAR	Same as Report
SF	Standard Form
SR	Special Report
SRI	Solar Reflectance Index
SRM	Sustainment, Restoration, and Modernization
SS	Sustainable Site
SW	Solid Waste
TD	Technical Director
TEMF	Tactical Equipment Maintenance Facilities
TRI	Toxic Release Inventory
TVOC	Total Volatile Organic Compounds
UEPH	Unaccompanied Enlisted Personnel Housing
UN	United Nations
URL	Universal Resource Locator
USA	United States of America
USACE	U.S. Army Corps of Engineers
USGBC	U.S. Green Building Council
VLT	Visible Light Transmittance
WBDG	Whole Building Design Guide
WFR	Window-to-Floor Area Ratio

Appendix A: Sample of “Green Building” Attributes by Other Organizations

U.S. Green Building Council Leadership in Energy and Environmental Design (LEED)

Sustainable Sites

- Site selection
- Development Density
- Brownfield Development
- Public transportation
- Bicycle storage & changing rooms
- Low emitting /fuel efficient vehicles
- Parking capacity
- Protect or restore habitat
- Maximize open space
- Storm water quantity control
- Storm water quality control
- Heat island, non roof
- Heat island, roof
- Light pollution reduction

Water Efficiency

- Landscaping water reduction
- Landscaping, no potable water use
- Innovative wastewater technologies
- Water use reduction

Energy & Atmosphere

- Fundamental commissioning
- Minimum energy performance
- Fundamental refrigerant management
- Optimize energy performance
- On-site renewable energy
- Enhanced commissioning
- Enhanced refrigerant management
- Measurement & verification
- Green Power

Materials & Resources

- Storage & collection of recyclables
- Building reuse, exterior
- Building reuse, interior
- C&D materials diversion
- Materials reuse
- Recycled content
- Regional materials
- Rapidly renewable materials
- Certified wood

Indoor Environmental Quality

- Minimum IAQ performance
- Environmental Tobacco Smoke (ETS) control
- Outdoor air delivery monitoring
- Increased ventilation
- Construction IAQ during construction
- Construction IAQ before occupancy
- Low emitting adhesives & sealants
- Low emitting paints & coatings
- Low emitting carpet systems
- Low emitting Composite wood
- Indoor chemical & pollutant source control
- Controllability of lighting
- Controllability of thermal comfort
- Thermal comfort design
- Thermal comfort verification
- Daylighting & views

Innovation in Design

- Innovation in Design
- LEED AP (Accredited Professional)

Technical Guidance for Implementing Executive Order 13143, Strengthening Federal Environmental, Energy, and Transportation Management

Guiding Principles

- Employ integrated design
- Optimize energy performance
- Protect & conserve water
- Enhance indoor environmental quality
- Reduce environmental impact of materials

Core Topics

- Integrated Design
- Commissioning
- Energy Efficiency
- Measurement & verification
- Indoor water conservation
- Outdoor water conservation
- Storm water run-off mitigation
- Ventilation & thermal comfort
- Moisture control
- Daylighting
- Low emitting materials
- Protecting IAQ during construction
- Recycled content
- Biobased content
- Construction waste
- Ozone depleting compounds

Supporting topics

- Renewable energy & green power
- Operations & maintenance
- Chemicals of concern
- Interior noise
- Sustainable sites/smart growth
- Creative funding strategies & life cycle cost (LCC)
- Making the environmental case
- Life Cycle Assessment
- Environmental Management Systems
- Selecting Architect/Engineer (AE) contractors
- Minor alterations & LEED EB
- Security & sustainability
- Working w/GSA, leasing
- BIM (Building Information Model)
- Post occupancy evaluations

Army Annual Sustainability Report

Mission

- Net cost of Army operations
- Army end strength, active
- Reserve end strength, Reserve & National Guard (NG)
- Environmental funding

Environment

- Cleanup, Formerly Used Defense Sites (FUDS) & environmental restoration
- Compliance, P2, Conservation
- Army facilities w/Energy Management Systems (EMSs) in place
- Installation sustainability plans
- New Army environmental enforcement actions
- Federal, state, & local inspections
- Violation rate
- SW & C&D debris generated
- Overall SW & C&D recycle rate
- Hazardous waste (HW) generated
- HW generated indexed to net cost of Army operations
- Toxic release inventory releases
- Toxic Release Inventory (TRI) releases indexed to net cost of Army operations
- Installations w/up to date integrated natural resource management plans
- New MILCON to LEED standards
- Army facility water use
- Facility energy use intensity
- Military accident fatalities rate

Community

- Army civilian lost time claims
- Retention
- Recruiting
- Net cost of CW fund
- Acres of habitat restored, created, improved, or protected
- Additional people protected from flood damage
- Acre-feet of wasted supply management
- Visits to Corps recreational areas

Global Reporting Initiative (as cited in the Army Annual Sustainability Report)

Materials

- Materials used by weight or volume
- Percentage of materials w/recycled input

Energy

- Direct energy consumption
- Indirect energy consumption
- Energy saved by conservation & efficiency improvements
- Initiatives to provide energy efficient or renewable energy
- Initiatives to reduce indirect energy consumption

Water

- Total water withdrawal by source
- Water sources significantly affected by withdrawal of water
- Percent & total volume of water recycled & reused

Biodiversity

- Location & size of land owned ... protected areas & areas of high biodiversity value
- Habitats protected or restored
- Strategies, actions, & plans for managing impacts on biodiversity
- Number of International Union for Conservation of Nature and Natural Resources (IUCN) red list species w/habitats affected by operations

Emissions, Effluents, & Waste

- Total direct GHG emissions
- Other relevant indirect GHG emissions
- Initiatives to reduce GHG emissions
- Emissions of Ozone-Depleting Substance (ODS)
- NOx, SOx, & other significant emissions
- Total water discharge by quantity & destination
- Total weight of waste by type & disposal method
- Total number and volume of significant spills
- Weight of imported, exported, or treated waste deemed to be hazardous

Products & Services

- Initiatives to mitigate environmental impacts of products & services
- Percentage of products sold & packaging materials reclaimed by category

Compliance

- Monetary value of significant fines & total of non-monetary sanctions for non-compliance

Transport

- Significant environmental impacts of transporting products & goods

Overall

- Total environmental protection expenditures & investment

PNNL Building Cost and Performance Metrics

Water

- Total Building Potable Water Use
- Indoor Potable Water Use
- Outdoor Water Use
- Total Storm Sewer Output

Energy

- Total Building Energy Use
- Source Energy
- Peak Electricity Demand

Maintenance and Operations

- Building Maintenance
- Grounds Maintenance
- Churn Cost

Waste Generation

- Solid Sanitary Waste
- Hazardous Waste
- Recycled Materials

Purchasing

- Environmentally Preferable Purchasing (EPP)

Indoor Environmental Quality

- Occupant Turnover Rate
- Absenteeism
- Building Occupant Satisfaction
- Self-Rated Productivity

Transportation

- Regular Commute

ASTM Standard E-2432, Standard Guide for General Principles of Sustainability Related to Buildings.

Environmental Principles

- Ecosystems
- Biodiversity
- Natural resources

Economic Principles

- External cost/benefits
- Social costs/benefits
- Environmental costs/benefits
- Life cycle costs/benefits
- First costs/benefits
- Operating costs/benefits
- End use costs/benefits

Social Principles

- Health, safety & welfare
- Transparency
- Equity

USDOE FEMP— A Business Case for Sustainable Design in Federal Facilities.

Sustainable Siting

- Site selection
- Site analysis – building/site relationship
- Facilitation of alternative transport use
- E&S control & stormwater management
- Reduced site disturbance during construction
- Sustainable landscape & exterior design
- Light pollution reduction

Water Efficiency

- Water use reduction

Energy Efficiency

- Space layout
- Building envelope
- Lighting & sun control
- Systems & equipment
- Renewable energy
- Energy load management

Sustainable Materials & Resources

- Storage/collection of recyclables
- Building & resource reuse
- Construction waste management
- Recycled content
- Waste prevention
- Local/regional materials
- Rapidly renewable materials
- Design for reuse

Indoor Environmental Quality

- IEQ
- Good visual quality
- Noise control
- Systems controls
- Commissioning & O&M
- Sustainable housekeeping & maintenance

Appendix B. Case Study Summaries and References

Estimated green building costs

“Building for Sustainability: Six Scenarios for the David and Lucile Packard Foundation, Los Altos Project.” October 2002.*

Project Description: The David and Lucile Packard Foundation[†] developed a decisionmaking method that would clearly explain the aesthetic, economic, schedule, and environmental impacts implied by the sustainability goals for their proposed office building using LEED®. They designed a conceptual building model for six scenarios in the form of building footprints, wall sections, and outline specifications. These scenarios are a market building scenario, constructing a LEED® certified building, a LEED® silver building, a LEED® gold building, a LEED® platinum building, and a “Living Building.”

Design/modeled/calculated performance compared to a non-LEED® building solution: The cost-estimating models for constructing the new office building determined that Certified LEED® rating estimate would cost 1.5 percent additional above the base cost. It would also take no additional time for additional design and documentation and no additional construction time from baseline. A Silver LEED® rating estimate would cost 13.5 percent above baseline. It would also take 3 additional months for additional design and documentation and an additional 3 months of construction time from baseline. A Gold LEED® rating estimate would cost 15.8 percent additional above base line. It would take 3 additional months for additional design and documentation and an additional 3 months for construction from baseline. A Platinum LEED® rating estimate would cost 22.2 percent additional above base line. It would also take 6 additional months for additional design and documentation and an additional 6 months of construction from base-

* The Packard Foundation Facilities Steering Committee. October 2002. *Building for Sustainability: Six Scenarios for the David and Lucile Packard Foundation, Los Altos Project.*

† Provides grants to nonprofit organizations in the following broad program areas: conservation; population; science; children, families, and communities.

line. The calculated annual energy consumption for a Certified LEED® building would be 49.2 percent lower than baseline, for a Silver LEED® building would be 93 percent lower than baseline, for a Gold LEED building would be 98 percent lower than baseline, and for a Platinum LEED® would be 96 percent lower than baseline.

Metrics Used: Implementation costs, energy savings.

Applicability to the Army: Just using the information provided, the cost to go certified LEED® would be 1.5 percent above the base cost. The cost to go to Silver LEED® would be 13.5 percent above the base cost. The cost to go Gold LEED® would be 15.8 percent above the base cost. The cost to go Platinum LEED® would be 22.2 percent above the base cost.

“GSA LEED® cost study”*

Project Description: GSA developed two different building scenarios, one of constructing a new courthouse and the other to remodel a Federal office building. They then developed seven different budgetary cost models for each building type of what extra cost it would take to “go green.” Those seven models were a baseline estimate, a high and low model to achieve basic LEED® certification rating, a high and low cost model to achieve Silver LEED® certification, and a high and low cost model to achieve Gold LEED® certification.

Design/modeled/calculated performance compared to a non-LEED® building solution:

The cost estimating models for constructing a new courthouse determined that Certified LEED® rating estimate ranges from a -0.4 percent to a 1.0 percent additional above the base cost, Silver LEED® rating estimate ranges from a -0.03 percent to a 4.4 percent additional above the base cost, and Gold LEED® rating estimate ranges from a 1.4 percent to a 8.1 percent additional above the base cost.

The cost estimating models for constructing a new courthouse determined that Certified LEED® rating estimate ranges from a 1.4 percent to a 2.1 percent additional above base cost, Silver LEED® rating estimate ranges from a 3.1 percent to a 4.2 percent additional above base cost, and Gold LEED® rating estimate ranges from a 8.2 percent to a 7.8 percent additional above the base cost.

* Steven Winter and Associates. October 2004. GSA LEED® Cost Study.

Metrics Used: Implementation costs.

Applicability to the Army: Just using the information provided, the cost to go certified LEED® will range from 0.4 percent to 2.1 percent above the base cost. The cost to go to Silver LEED® will range from -0.03 percent to 4.2 percent above the base cost. The cost to go Gold LEED® will range from 1.4 percent to 8.1 percent above the base cost.

Estimated or modeled savings

“Energy Savings and Performance Gains in GSA Buildings: Seven cost-effective strategies”*

Project Description: This project surveyed over 6000 Federal workers and measured environmental conditions at 624 workstations in 43 workplaces in 22 separate buildings representative of building ages, workplace types, and climate zones from the total GSA building inventory.

Design/modeled/calculated performance compared to a non-LEED® building solution: The study identified seven key areas that offer the potential for significant performance gains with a calculated potential energy savings for GSA’s entire inventory of 176.4 million square feet:

Strategy	Energy Savings
Adjust workplace temperature for the summer months by the ambient temperature from 74 to 78	18.7 million kWh/yr
Replace heating, ventilating, and air-conditioning (HVAC) filters <u>on schedule</u> and with high performance filters	10.8 million kWh/yr
Consolidate and reduce the number of printers and copiers to one per 25 employees	55.0 million kWh/yr
Replace CRT monitors with LCD monitors	39.0 million kWh/yr
Upgrade ambient and task lighting in the workplace by replacing inefficient T-12 bulbs with T-8 bulbs	199.1million kWh/yr
Improve access to daylight in the workplace	118.1 million kWh/yr
Upgrade single pane to double pane windows for better performance	127.5 million kWh/yr
Total	568.2 million kWh/yr

This will equate to approximately (568.2 million kWh/yr/176.4 million sq ft) 3.22 kWh/yr/sq ft.

* *Energy Savings and Performance Gains in GSA Buildings: Seven Cost-Effective Strategies*. March 2009. GSA Public Building Service.

Metrics Used: Energy savings.

Applicability to the Army: Assuming that the Army could implement these savings to just 50 percent of their inventory and paying an average of \$0.08/Kwh), the savings would be:

$$1,013 \text{ million sq ft} * 50\% * 3.22 \text{ kWh/yr/sq ft} * \$0.08/\text{kWh} = \$130 \text{ million/yr.}$$

“Improving the Energy Performance of Buildings: Learning from the European Union and Australia”[†]

Project Description: The European Union and the Australian Commonwealth in recent years have pioneered policies to promote energy efficiency in existing buildings. This study examined how these policies have worked and draws implications for the design of similar public policies for the United States.

Design/modeled/calculated compared to a non-LEED® building solution: The legislative policies focus primarily on the owner’s standard operation building energy used (e.g., heating and cooling), not on energy used within a building by its occupants. For example, the legislation will require an owner to improve the building’s energy performance by using better windows and insulation, but it would have no effect on the energy consumption of a tenant. Legislative efforts focused on upgrading/improving building codes, using energy efficiency certificates so that tenants will start to value efficient energy performance, implementing a media campaign to promote energy efficiency in public buildings, requiring training and certification of experts, and white-certificate programs.

Metrics Used: Energy savings.

Applicability to the Army: Some of these ideas are currently being implemented for the Army. For example, the Army is currently using LEED® to help achieve improved energy performance (building codes), promoting energy efficiency and savings, and making training available for designers.

* *An Overview of the U.S. Government’s Real Property Assets*. The Federal Real Property Council. August 2009, FY 2008 Federal Real Property Report, p 8

† Charles P. Ries, Joseph Jenkins, and Oliver Wise. 2009. *Improving the Energy Performance of Buildings Learning from the European Union and Australia*. Rand Corporation.

“Climate Friendly Buildings and Offices: A Practical Guide”*

Project Description: The guide’s aim is to assist UN organizational offices in becoming “climate friendly,” meaning that offices will generate lower GHG emissions during their operation than would be standard practice. They UN based these guides on research and not on any specific examples.

Design/modeled/calculated performance compared to a non-LEED® building solution: The UN estimated that GHG emissions in 2004 are 8.16 million CO₂ equivalent metric tons. They also feel that GHG emissions (through energy consumption) in both new and existing buildings can be cut by an estimated 30–50 percent without significant increases in investment costs. The report gives 63 specific ways on how to reduce green house gases under the categories of energy supply and distribution, operations and maintenance, lighting, HVAC, building envelope, office equipment, and GHG compounds and equipment. Each item gives an approach of how to implement the idea, benefits, technical requirements, cost, and payback (giving mostly ROR [rate of return]), and risks.

Metrics Used: Reducing green house emissions.

Applicability to the Army: The UN’s guidance might be a starting point for the Army in developing their own GHG Emission criteria.

Actual building and data comparisons

“The Economics of LEED for Existing Buildings for Individual Buildings 2008 Edition”†

Project Description: The Leonardo Academy‡ surveyed 23 existing buildings in the market place to find out what it took to become LEED®-EB. They gathered information in three areas: the certification cost to document and submit the information to U.S. Green Building Council for LEED®-EB, the cost to install the required LEED®-EB features that resulted in improved performance, and the building operation cost.

* *Climate Friendly Buildings and Offices: A Practical Guide*. A United Nations Environment Programme Report. 2010

† Leonardo Academy. 2008. *The Economics of LEED for Existing Buildings for Individual Buildings*. 2008 Edition.

‡ Leonardo Academy is a charitable non-profit organization dedicated to advancing sustainability and putting the competitive market to work on improving the environment.

Objectives relative to performance: The survey showed that the LEED®-EB implementation cost should not be a barrier because there are many “low/no cost” credits available that can be implemented right away. The environmental benefits of the “low/no” cost measures can be accumulating while plans are made to implement the costlier actions.

Cost investment paid to achieve green: The mean total cost of submitting documentation and implementing LEED®-EB features for all buildings was \$1.59/sq ft, with a range of \$0.02 to \$5.00. The mean total costs for the different certification levels show a trend for increased cost for higher levels, with the mean total costs for Certified at \$1.60/sq ft, Silver at \$1.22/sq ft, Gold at \$1.73/sq ft, and Platinum \$1.84/sq ft. The survey also demonstrated that many of the measures in LEED®-EB are “low” and “no cost” to implement, thereby lowering the implementation costs.

Design or actual performance compared to a non-LEED® building solution: Sixty-four percent of the LEED®-EB buildings had operation and maintenance costs of \$6.68/sq ft performing better than the regional average at \$6.85/sq ft. The survey also separated out the actual utility cost from the operation and maintenance costs. The utility costs of 64 percent of the LEED®-EB buildings were \$1.76/sq ft, better than the regional average of \$2.09/sq ft.

Other benefits: The report only indicates that there are many other economic benefits of LEED®-EB certification that are becoming apparent. Among them are increased occupant productivity, increased ability to recruit high quality employees, reduced employee turnover, reduced insurance costs, and potential for reduced health care costs.

Metrics Used: Implementation cost, O&M cost.

Applicability to the Army: The Army could also upgrade existing buildings, at a modest investment, to LEED®-EB, thereby reducing operational and maintenance costs and improving environmental performance.

Review of the LEED Points Obtained by Canadian Building Projects *

Project Description: This paper reviewed the Canadian LEED® system usage in building construction and the potential challenges and

* Da Silva, Lucas, and Janaka Y. Ruwanpura. June 2009. “Review of the LEED Points Obtained by Canadian Building Projects.” *Journal of Architectural Engineering*. American Society of Civil Engineers.

barriers associated with LEED® implementation that specifically pertain to Canadian circumstances. They collected and analyzed information from 42 new LEED® certified construction projects across Canada. They tabulated the most often awarded points, as well as those that are granted the least frequently.

Objectives relative to performance: The paper used credit frequency indicators (CFIs) to depict the frequency of a particular LEED® credit achievement by each project. They found out that the categories of “energy and atmosphere” and “materials and resources” categories proved to have the lowest CFIs, whereas the “innovation and design process” and “water efficiency” categories yielded the highest CFIs. The study also found that there were differences in the points obtained by LEED® projects in Canada and the United States are influenced by climate, such as weather and temperature, as well as regional location.

Cost investment paid to achieve green: This study dealt with the frequency LEED® credits and did not include any information on investment to “go green.”

Design or actual performance compared to a non-LEED® building solution: The points most frequently awarded, as well as those least frequently awarded are: The ID1.1 and ID2 (innovation in design and LEED® accredited professional) credits yielded points to all 42 Canadian projects. The next highest percentage of achievement was for credits WE3.1 (water use reduction, 20 percent), MR5.1 (local/regional materials, 10–20 percent manufactured locally), and SS4.2 (bicycle storage and change rooms) at 98 percent, followed by WE1.1 (water efficient landscaping, reduced by 50 percent) and ID1.2 (innovation in design 2) at 95 percent. The credits with the lowest percentage of use were MR1.3 (building reuse, maintain 50 percent of interior non-structured elements) at 0 percent, MR1.2 (building reuse, maintain 95 percent of existing walls, floors, and roof) at 2 percent, and MR6 (rapidly renewable materials), EA2.3 (renewable energy, 20 percent), and MR1.1 (building reuse, maintain 75 percent of existing walls, floor, and roof) at 5 percent. It should be noted that all of the Canadian LEED® projects included in this study were new construction projects; therefore, the low percentages for building reuse credits is not surprising.

Other benefits: Understanding how projects have used LEED® credits in the past will improve the application of sustainable features in future sustainable development. In turn, this will help minimize

the negative effects of design and construction efforts on the natural environment and the people that come in contact with them.

Project teams will be able to more effectively implement LEED®.

Metrics Used: Energy savings, O&M cost, water usage, reducing green house emissions, IEQ.

Applicability to the Army: Certain LEED® credits are easily obtainable.

“Costing Green: A Comprehensive Cost Database and Budgeting Methodology”*

Project Description: This paper uses extensive data on “green” Academic, Laboratory, and Library building costs to compare the cost with comparable buildings, which do not have sustainable goals. It discusses feasibility of each LEED® point and the frequency of which that credit is obtained, based on the points either earned or being attempted by the projects studied.

Objectives relative to performance: The authors found that implementing some of the LEED credits will result in no additional cost to a project, while others may result in an identifiable cost. They found out that the categories of “innovation and design process” and “materials and resources” categories received the fewest credits, whereas the “indoor air quality” category received the most credits. This suggests that owners are finding ways to incorporate project goals and values, regardless of budget, by making choices.

Cost investment paid to achieve green: This study evaluated the LEED® implementation cost of Academic buildings, Laboratories, and libraries and found that there is no significant statistical difference between the average implementation costs per square foot for LEED® -seeking versus non- LEED® buildings.

Design or actual performance compared to a non-LEED® building solution: The points most frequently awarded are: ID2 (innovation in design and LEED® accredited professional), IE3.1 (Construction Management IAQ plan during construction), IE3.2 (Construction Management IAQ plan before occupancy), IE4.1 (Low Emitting Materials adhesives and sealants), IE4.2 (Low Emitting Materials paints and coatings), IE4.3 (Low Emitting Materials Flooring Systems), and MR2.1 (Construction Waste Management diverting 50

* Lisa Fay Matthiessen and Peter Morris. July 2004. *Costing Green: A Comprehensive Cost Database and Budgeting Methodology*. Davis Langdon and Associates.

percent from landfill). The credits with the lowest percentage of use were MR1.1 (Building reuse, maintain 75 percent of existing walls, floor, and roof), MR1.2 (building reuse, maintain 95 percent of existing walls, floors, and roof), MR1.3 (Building reuse, maintain 50 percent of interior nonstructural elements), MR3.2 (Resource reuse, 10 percent), SS3.0 (Brownfield redevelopment), and EA5.1 (Measurement & verification). All of the projects are “New Construction” and therefore, it is no surprise that building reuse credits were infrequently used.

Other benefits: Understanding how projects have used LEED® credits in the past will improve the application of sustainable features in future sustainable development. In turn, this will help minimize the negative effects of design and construction efforts on the natural environment and the people that come in contact with them. Project teams will be able to more effectively implement LEED®.

Metrics Used: Energy savings, O&M cost, water usage, reducing green house emissions, IEQ.

Applicability to the Army: This analysis showed that many projects can achieve sustainable design within their initial budget, or with very small supplemental funding.

Greening America's Schools: Costs and Benefits*

Project Description: This report is intended to answer the question, “How much more do green schools cost and is greening schools cost effective?” The report data are drawn from 30 green schools built in 10 states during the period 2001 to 2006. The data on costs as well as savings compared to a conventional design were generally supplied by the schools’ architects. Some of the costs analyzed in the report are based on actual building performance, while some new school costs are estimates based on architectural modeling and engineering estimates.

Objectives relative to performance: Reduced energy consumption in green schools has two distinct financial benefits: (1) direct reduction in school energy costs, and (2) indirect secondary impact from reduced overall market demand and resulting lower energy prices market-wide

* Gregory Kats and Jon Braman. October 2006. *Greening America's Schools: Costs and Benefits*. A Cap E report for U.S. Green Building Council.

Cost investment paid to achieve green: Four of the green schools (in Georgia, Massachusetts and Oregon) cost no more than conventional design, while several schools cost substantially more. Six schools cost at least 3 percent more than conventional design while one – the Punahou School in Hawaii – costs 6.3 percent more. Typically green schools cost 1 to 2 percent more, with an average cost premium of 1.7 percent, or about \$3/sq ft.

Design or actual performance compared to a non-LEED® building solution: The report documents that a national review of 30 green schools demonstrates that green schools cost less than 2 percent more than conventional schools — or about \$3/sq ft (\$3/sq ft) — but provide financial benefits that are 20 times as large, or about \$70 per sq ft. Part of this financial benefit includes lower energy and water costs, improved teacher retention, and lowered health costs that save green schools directly about \$12/sq ft, about four times the additional cost of going green. For an average conventional school, building green would save enough money to pay for an additional full-time teacher. Green schools use an average of 33 percent less energy than conventionally designed schools and achieve an average water use reduction of 32 percent.

Other benefits: Greening school design provides an extraordinarily cost-effective way to enhance student learning, reduce health and operational costs and, ultimately, increase school quality and competitiveness. Financial savings to the broader community are significantly larger, and include reduced cost of public infrastructure, lower air and water pollution, and a better educated and compensated workforce.

Metrics Used: Implementation cost, energy savings, water-related savings.

Applicability to the Army: This analysis showed that many projects can achieve sustainable design within their initial budget or just slightly over the initial budget and develop some direct, observable financial impacts and sustained benefits over a significant period.

Actual energy, water, and other items savings.

“Assessing Green Building Performance: A Post Occupancy Evaluation of 12 GSA Buildings”*

Project Description: This study evaluated the impact of GSA’s 12 sustainably designed buildings in 2007 located throughout the United States by collecting and analyzing actual performance data over a year for comparison to industry building performance baselines. GSA, the USDOE, International Facility Management Association (IFMA), Building Owners and Managers Association International (BOMA), U.S. Environmental Protection Agency, University of California Berkeley’s Center for the Built Environment, and the Energy Information Administration developed the performance baselines used in this study.

Objectives relative to performance: The sustainably designed buildings investigated overall reduction in cost to operate, improve energy performance, and maintain occupants more satisfied with the overall building performance than the occupants in typical commercial buildings.

Cost investment paid to achieve green: This study dealt with analyzing performance data and did not include any information on investment to “go green.”

Design or actual performance compared to a non-LEED® building solution: The study found that the energy used in 75 percent of the LEED® buildings were performing better than the baseline typical building. It also found that two-thirds of the study building’s water use values were better than or at the baseline. Additionally, all of the occupant satisfaction scores were higher than baseline. Finally, 66 percent of the buildings have aggregate maintenance costs, consisting of utility cost, general maintenance cost, grounds maintenance, waste and recycling costs, and janitorial costs, are 13 percent below the baseline.

Other benefits: The survey mentioned two other areas where the survey buildings had significant benefits—by reducing GHGs and IEQ. Less than half of the survey buildings had an average commute distance less than the industry average of 25 miles daily. Only two buildings have CO₂ equivalent emissions greater than the baseline

* Kim M. Fowler and Emily M. Rauch. July 2008. *Assessing Green Building Performance: A Post Occupancy Evaluation of 12 GSA Buildings*, Pacific Northwest National Laboratory.

due to community population size. From this, it can be observed that more people in these buildings use mass transit, non-motorized transportation, or more fuel efficient vehicles and thereby are reducing GHGs. The IEQ of all of the GSA study buildings scored above the 50th percentile in comparison to the industry baseline, and overall the occupants are satisfied with their buildings.

Metrics Used: Energy savings, O&M cost, water usage, reducing green house emissions, IEQ.

Applicability to the Army: The success rate of implementing LEED® features can vary from location to location. However, taking the site information and aggregating the information can show substantial savings.

“Doing well by doing good? An analysis of the financial performance of green office buildings in the USA”*

Project Description: This project looked at a total of 694 rated buildings and 7488 control buildings that were located within 1300 feet of the rated buildings to relate contract rents and effective rents to a set of objective building characteristics, holding constant the locational property characters.

Objectives relative to performance: The empirical results suggest that customers may be willing to pay a premium for the “socially responsible” attributes of green buildings. Alternatively, for owners it may be a successful marketing strategy to offer rated and labeled buildings in the marketplace.

Cost investment paid to achieve green: This study dealt with analyzing rental rates of existing “Green” buildings and did not include any information on investment to “go green.”

Design or actual performance compared to a non-LEED® building solution: The study found that buildings with a “green rating” command rental rates that are roughly 2 percent higher per square foot than otherwise identical buildings. Premiums in expected rents, i.e., rents adjusted for building occupancy levels, are even higher – above 6 percent.

* Piet Eichholtz, Nils Kok, and John Quigley. 02 April 2009. *Doing Well by Doing Good? An Analysis of the Financial Performance of Green Office Buildings in the USA*, <http://www.greenbiz.com/buildings/research/report/2009/04/02/doing-well-doing-good>

Other benefits: The study also concluded that the investment in eco-efficient or green buildings could lead to economic benefits in at least four ways. First, investments at the time of construction or renovation may: save current resources expended on energy, water and waste disposal; decrease other operating costs; ensure against future energy price increases; and simultaneously decrease GHG emissions. Second, an improved IEQ in green buildings might result in higher employee productivity. Third, locating corporate activities in a green building can positively affect the corporate image of tenants. Fourth, sustainable buildings might have longer economic lives – due to less depreciation – and lower volatility – due to less environmental and marketability risk – leading to reduced risk premiums and higher valuations of the properties.

Metrics Used: Rental rates.

Applicability to the Army: The Army has a small amount of buildings that it leases to customers. There are also a number of tenant facilities on an installation. By having a “green” building could help the Army get a better rental rate and charge more for maintenance of tenant facilities.

“Energy Performance of LEED for New construction Buildings”*

Project Description: This study analyzes the measured energy performance for 121 LEED® New Construction (NC) buildings, providing a critical information link between intention and outcome for LEED® projects.

Objectives relative to performance: The results show that projects certified by the USGBC LEED® program, on average, have a substantial energy performance improvement over non-LEED® building stock.

Design or actual performance compared to a non-LEED® building solution: For all 121 LEED® buildings, the median measured Energy Use Intensity (EUI) was 69 kBtu/sq ft, 24 percent below (better than) the national average for all commercial building stock. Measured energy savings for the buildings in this study average 28 percent compared to code baselines, close to the average 25 percent savings predicted by energy modeling in the LEED® submittals.

Metrics Used: Energy savings.

* Cathy Turner and Mark Franke. 4 March 2008. *Energy Performance of LEED® for New Construction Buildings: Final Report*. New Building Institute.

Applicability to the Army: The Army could see a significant savings in its utility costs by “greening” its buildings.

“Greening Our Built World, Costs, Benefits, and Strategies”*

Project Description: The book explores to answer the fundamental question of whether the benefits of green design outweigh the costs by looking at the data from 170 buildings in nine countries. And, critically, if green design is broadly cost effective, how large an impact could greening have on a clean energy economy and slow global warming.

Objectives relative to performance: Greening buildings are generally cost-effective compared to conventional development and design, which can be plagued with risk and financial imprudence. These buildings typically achieve substantially greater efficiency than just investments in energy efficiencies alone as the look at the “bigger picture.”

Cost investment paid to achieve green: The 186 buildings in the data set reported premiums ranging from 0 to 18 percent with a median of 1.5 percent additional cost to “go green” for new construction. These figures then translate into a typical added cost of building a green building is between \$3 to \$9/sq ft. They also report that to achieve a “green” rating for an existing building has a median of 1.9 percent additional cost to implement the “green” features.

Design or actual performance compared to a non-LEED® building solution: Actual performance savings came in energy savings, GHG emissions, and water-related savings. For energy, the data show a range of projected and actual reductions in energy use from less than 10 percent to more than 100 percent (meaning that the building generates more than it can use) with a median reduction of 34 percent. In terms of dollars this means an annual energy savings ranges from \$0.20/sq ft to over \$1.0/sq ft with a median of \$0.50/sq ft. For GHG emissions costing roughly \$20/ton, they calculated the present value savings to be between \$1/sq ft and \$2/sq ft. For water-related savings, 64 percent of the buildings reported actual savings or projected reductions in indoor potable water use when compared to conventional buildings. These savings

* Greg Kats, Jon Braman, and Michael James. 2010. *Greening Our Built World, Costs, Benefits, and Strategies*. Island Press.

ranged from 0 percent to 80 percent with a median of 39 percent. The net present value of water savings ranges from \$0.50/sq ft to \$2/sq ft.

Other benefits: The author expressed the opinion that there could be a number of indirect savings that could be obtainable from “greening.” For example, investing in water-related saving measures could eliminate a portion of future water and wastewater investments, including the need for new and expensive sources of potable water or wastewater treatment methods. The author also expressed the opinion that it would reduce energy consumption required to run the water and wastewater conveyance and treatment systems. Greening affordable housing can contribute to fight climate change—weatherizing a house can cut more than 50 tons of SO₂ and 24,000 tons of CO₂ per year and utility bills by hundreds of dollars. Reducing energy usage could avert the need for new energy sources and new transmission and distribution capacity. Furthermore, efficiency-driven reductions in demand can have a significant impact on price. Additionally, he indicated that a reduction in natural gas consumption could drive a deduction in long-term natural gas prices.

Metrics Used: Energy savings, water savings, GHG emissions.

Applicability to the Army: The Army could see a significant savings in its utility costs by “greening” its buildings.

“High Performance Green Buildings: What’s it worth? Investigating the Market Value of High Performance Green Buildings”*

Project Description: This study looked at three buildings, “Alley24” located in Seattle, WA, “200 Market Place” in Portland, OR, and “Vancouver Centre” in Vancouver, BC to determine the answer one question, “Are high performance green buildings really worth more than traditional buildings?” To explore this question, two leading experts were recruited to analyze and ascertain whether high performance green attributes contributed to market values

Objectives relative to performance: All three projects were successful at the triple bottom line philosophy. The three principles of the triple bottom line philosophy are generating a market return on in-

* Theddi Wright Chappell, Chris Corps, and Brandon Smith, May 2009. *High Performance Green Buildings: What’s it worth? Investigating the Market Value of High Performance Green Buildings*. Cascadia Region Green Building Council.

vestments, making a positive impact on the community through quality design and development, and protecting the environment through high performance green development

Cost investment paid to achieve green: The certification costs for Alley24 East represented 0.2 percent of the total construction cost and are below the USGBC average LEED® Silver certification costs. The certification costs for 200 Market Place represented 0.2 percent of the total construction cost and are below the USGBC average LEED® Gold certification costs.

Design or actual performance compared to a non-LEED® building solution: Alley24 experienced a comparatively quick absorption period; attracted and retained high quality tenants; achieved competitive rents; and has a higher-than average occupancy level. This is all due to three items. First, the building occupants had high or moderately high scores related to building temperature, air quality, acoustics, lighting, and general health and productivity factors. Second, they showed significant energy (23 percent) savings. Finally, they also had water savings (30 percent).

Prior to LEED® certification, 200 Market Place had escalating energy consumption each year from 2004 through 2006. However, since LEED® certification in 2006, energy use declined in 2007 by 3.45 percent and in 2008 by 8.73 percent. Most of the savings resulted from installing a 30kW natural gas micro-turbine, which was a feature installed for LEED® certification. Additionally, from 2007 to 2008, overall operating expenses declined by 0.64 percent, and they are projected to decline by an additional 3.29 percent in 2009. The building implemented a stormwater management plan, which reduced stormwater runoff by over 50 percent.

The Vancouver Centre implemented a rolling renovation program to overcome capital plant and equipment (e.g., HVAC, lighting) obsolescence and the potential to improve energy performance with resultant savings. They found that the energy retrofit project achieved a 19 percent ROI, with a payback of 4 years. Two years after project completion, the Centre had saved over 12.7 million kWh of electricity and almost 29 million pounds (43,000 GJ) of steam, for a total cost savings of C\$1.2 million. This equates to a 20 percent reduction in their electricity use and a 31 percent reduction in their steam use compared to the base period. The Centre also reduce water usage reporting a savings of 6468 cu ft, (or 183,153 L), or 21 percent in 2006, equaling approximately C\$16,000.

Other benefits: The 200 Market place projected noted that properties exhibiting the greatest success in adopting and effectively implementing high performance green strategies have talented building engineers who have played a critical role in the incorporation and long-term success of the strategies employed. Owners of successful green buildings often report that their chief engineers are dedicated to ensuring that the buildings will achieve optimum systems performance and deliver maximum tenant satisfaction. The Vancouver Center incidental finding that the relationship between landlord and tenant might be structured to support a sustainable retrofit for mutual profit.

Metrics Used: Energy savings, IEQ.

Applicability to the Army: The Army could not only see a savings in energy and water usage by implementing a LEED-NC/EB standard; they could also see a significant reduction in steam usage. These projects also show a significant rate of investment over a relative short time.

“LEED® Building Performance in the Cascadia Region: A Post Occupancy Evaluation Report”*

Project Description: This report gives an initial look at some actual performance results over a year of 11 LEED® certified buildings with respect to energy efficiency, water efficiency, and occupant satisfaction in the Cascadia Region. The report looked at energy and water efficiency as actual versus design, actual versus baseline, and actual versus comparable buildings in the area. For occupant satisfaction, the survey determined perceptions of building comfort and functionality in the categories of temperature, air quality, lighting, noise, and plumbing fixtures.

Objectives relative to performance: Most buildings in this study are experiencing real energy savings in relation to their original design and baseline modeling. For example, seven out of 11 buildings are using less energy than the design values and all are using less energy than the baseline. Water, on the other hand, had a different story. Ten out of 11 buildings used slightly more than the design values. This could be due to the fact that irrigation water was not

*Cathy Turner. 2006. *LEED® Building Performance in the Cascadia Region: A Post Occupancy Evaluation Report*. Prepared for the Cascadia Region Green Building Council.

metered separate from indoor water and also because some of the buildings were multi-use.

Cost investment paid to achieve green: The report did not give any costs of what took to “go green.”

Design or actual performance compared to a non-LEED® building solution: Six of the buildings were using less total energy than suggested by their initial Design models. All buildings used less energy than their initial baseline modeling, averaging nearly 40 percent below baseline. All but two of the study buildings show savings in actual energy compared to comparable buildings in the area. Of the seven buildings for which there was water data available, all but one used slightly more than their design values. Additionally, four buildings were saving more than 8 percent of their initially projected baseline water usage. Satisfaction ratings for most categories, with the exception of noise level and sound privacy, were typically positive. Light levels and air quality were both generally perceived as being somewhat helpful in getting work done. The dissatisfaction with noise levels and sound privacy has also been reported on surveys by others, and is often associated with open office environments. Workspaces of survey respondents were typically low partition cubicles or desks with no partitions.

Other benefits: The authors expressed the opinion that capturing key information relating to initially expected building performance might facilitate understanding actual performance levels without full design model recalibration. The information to capture would include: key modeling assumptions, changes made to efficiency features during construction and value-engineering, the main reasons for particularly high or low expected energy usage in the initial design model, metering and a better understanding of usage patterns.

Metrics Used: Energy savings, water-related savings, IEQ.

Applicability to the Army: The Army could see a significant savings in its energy costs by “greening” its buildings. It might be able to see a savings in water usage if there were metering and a better understanding of usage patterns.

“Managing the Cost of Green”*

Project Description: This report begins to address how to economically build green non-office projects, primarily in California. It does this by gathering information from a number of sources to provide general cost-saving strategies for building green, and by exploring the cost issues associated with “green” schools, laboratories, libraries, and multi-family affordable housing.

Objectives relative to performance: Despite existing barriers to incorporate green design, there are many opportunities to manage and minimize these costs. The report determined and presented strategies for increasing the efficiency of project managers and design teams attempting to build green, local conditions, managing design, project and construction costs, and maintaining the “green” facility.

Cost investment paid to achieve green: The report shows that, to obtain LEED® certification would cost from 0 to 2.5 percent above base costs, to obtain a LEED® Silver would cost from 0 to 3.4 percent above base costs, to obtain LEED® Gold would cost from 0.5 to 5 percent above base costs, and to obtain LEED® Platinum would cost from 4.6 to 8.5 percent above base costs. The study also found out that, if the owner would invest an additional 3 percent of total project costs during design, it would yield 10 percent savings in construction costs through design simplifications and reduced change orders.

Design or actual performance compared to a non-LEED® building solution: The cost to achieve LEED certification can depend on a variety of factors and assumptions, including: type and size of project; timing of introduction of LEED® as a design goal or requirement; level of LEED® certification desired; composition and structure of the design and construction teams; experience and knowledge of designers and contractors or willingness to learn; process used to select LEED® credits; clarity of the project implementation documents; and base case budgeting assumptions. The factors that add cost to green building projects may be grouped in categories relating to local conditions, the project, the design, the construction, and the operations and maintenance. The top five barriers to controlling costs are: lack of a clear green design goal; mid-stream attempts to incorporate green; decentralized manage-

* Geoff Syphers, Mara Baum, Darren Bouton, and Wesley Summons. October 2003. *Managing the Cost of Green*.

ment of the green building process; lack of experience/knowledge with green building; and insufficient time/funding.

Other benefits: Having a mechanical, electrical, and plumbing firm (MEP) throughout the total design process would result in savings equal to at least 10 percent of the MEP construction costs. Furthermore, if the owner would write Requests for Proposals (RFPs) and contracts that clearly describe green building requirements it would save time and as much as half the costs associated with implementing LEED®. Finally, projects that keep budgets separate (base vs. green), or put most green measures as alternates in specifications, typically end up costing more.

Metrics Used: Implementation cost.

Applicability to the Army: There are many factors that will influence the implementation costs, the construction costs, and local barriers to “go green.” Even with all these factors, there are significant observable savings.

“Occupant Satisfaction with Indoor Environmental Quality in Green Buildings”^{*}

Project Description: For the past several years, the Center for the Built Environment (CBE) at the University of California, Berkeley, has been conducting a survey that assesses IEQ in of 21 LEED® buildings and 160 baseline office buildings. The survey measures occupant satisfaction and self-reported productivity in nine IEQ categories in an anonymous, invite-style web-based questionnaire.

Objectives relative to performance: Comparing the survey’s results of LEED®-rated/green buildings with the baseline buildings, the study found that, on average, occupants in LEED®-rated/green buildings are more satisfied with their office furnishings, thermal comfort, air quality, cleaning and maintenance, and overall satisfaction with workspace and building. Conversely, the study saw that lighting and acoustic quality in green buildings do not show a significant improvement in comparison to non-green buildings.

Cost investment paid to achieve green: This study dealt with analyzing the IEQ of existing “Green” buildings compared to “non-

^{*} S. Abbaszadeh, L. Zagreus, D. Lehrer, and C. Huizenga. 2006. *Occupant Satisfaction with indoor Environmental Quality in Green Buildings*. Center for the Built Environment. University of California.

green” buildings and did not include any information on investment to “go green.”

Design or actual performance compared to a non-LEED® building solution: The study found that occupants in LEED®-rated/green buildings are, on average, more satisfied with their thermal comfort and air quality in their workspace than occupants in the baseline buildings.

Other benefits: This study did not provide any additional benefits.

Metrics Used: Indoor air quality.

Applicability to the Army: There are many items that can be accomplished to have satisfied building workers. This implies that, if the building workers are satisfied, they will be more productive.

“Regional Green Building Case Study Project: A post-occupancy study of LEED® projects in Illinois. Final Report Fall 2009,”*

Project Description: This case study analyzed the post-occupancy performance, costs, and benefits of 25 LEED® buildings, mostly in the greater Chicago, IL area for a year. The study looked at information related to measured energy and GHG emissions, water, commute transportation, construction and operating costs, green premium, health and productivity impacts, and occupant comfort.

Objectives relative to performance: There was a wide variation in measured performance among the projects related to measured energy and GHG emissions, water, commute transportation, construction and operating costs, green premium, health and productivity impacts, and occupant comfort. The study concluded that ongoing performance measurement and analysis is critical to quantify a building’s environmental impacts and efficiency over its lifecycle. A building’s best benchmark is its own performance. Since every building is unique in its use, occupancy, operations, maintenance and systems, actual post-occupancy measured performance that reflects actual operating conditions of the specific building will be the best benchmark. Individual building measured performance baselines provide the best benchmarks for building owners to set realistic, achievable, continuous improvement goals.

* Grand Victoria Foundation supported by USGBC. Fall 2009. *Regional Green Building Case Study Project: A post-occupancy study of LEED® projects in Illinois. Final Report.*

Cost investment paid to achieve green: The median project cost was \$211.16/sq ft with an additional amount to achieve LEED® certification was \$7.26/sq ft or 3.8 percent more.

Design or actual performance compared to a non-LEED® building solution: The study found better performance in four areas of energy usage, GHG emissions, and water usage. Specifically, the median energy usage for the buildings is 94 kBtu/sq ft/yr performing 5 percent better than the regional average of 99 kBtu/sq ft/yr. The median GHG emissions performance of 25.6 pounds/sq ft/yr CO₂ equivalent emissions is better than the calculated baseline. The median water usage is 873,000 gal/yr and is performing better than the baseline. Eight buildings reported reductions in operating costs.

Other benefits: The study also addressed three areas that could provide some additional benefits in the areas of occupant satisfaction, health, and commuting distance. Overall, occupant satisfaction is high especially related to indoor air quality and lighting. However, health and other benefits were not well documented to determine any specific benefits. The median distance that workers had to travel to work in these facilities is 8.2 miles, one-way, of which 89 percent of the travelers did it in their own car. The national average is 12.1 miles.

Metrics Used: Energy savings, reducing GHG emissions, water savings.

Applicability to the Army: The success rate of implementing individual LEED® features can vary from location to location. However, taking the site information and aggregating the information can show substantial savings.

“The Costs and Financial Benefits of Green Buildings: A Report to California’s Sustainable Building Task Force, October 2003”*

Project Description: In September 2002, California’s Sustainable Buildings Task Force undertook an economic analysis project to aid in the effort to evaluate the cost and benefits of sustainable building. They gathered cost data on 33 individual LEED registered projects (25 office buildings and eight school buildings) with actual or projected dates of completion between 1995 and 2004. These 33 projects were chosen because relatively solid cost data for both ac-

* Greg Kats, Leon Alevantis, Adam Berman, Evan Mills, and Jeff Perlman. October 2003. *The Costs and Financial Benefits of Green Buildings: A Report to California’s Sustainable Building Task Force*.

tual green design and conventional design was available for the same building.

Objectives relative to performance: The financial benefits of green buildings include lower energy, waste disposal, and water costs, lower environmental and emissions costs, lower operations and maintenance costs, and savings from increased productivity and health. These benefits range from being fairly predictable (energy, waste, and water savings) to relatively uncertain (productivity/health benefits).

Cost investment paid to achieve green: The average premium for these green buildings is slightly less than 2 percent (or \$3-5/sq ft), substantially lower than is commonly perceived of 10 to 15 percent higher. The majority of this cost is due to the increased architectural and engineering (A&E) design time necessary to integrate sustainable building practices into projects.

Design or actual performance compared to a non-LEED® building solution: Regarding energy, the building energy average annual cost is approximately \$1.47/sq ft for all buildings in California. On average, green buildings use 30 percent less energy than conventional buildings. The 20-year present value of expected energy savings is worth over half a million dollars for a 100,000/sq ft. Regarding water-related savings, water-related savings from green buildings would generate a 20-year present value of \$0.51/sq ft, which is very likely conservative (low). Regarding GHG Emissions, the study assumed a \$5 per ton value of carbon, and therefore, the savings from emissions reductions of green buildings indicate a 20-year PV of \$1.18/sq ft. Regarding waste reduction, there was a reduction of construction waste of at least 50 percent in 81 percent of the study buildings. However, the green building waste reduction advantage would not exceed ~\$0.50/sq ft, because of California's already aggressive waste reduction targets. Regarding IEQ, for California state employees, a 1.5 percent increase in productivity would equal \$998 per year, or \$4.44/sq ft per year. At \$4.44/sq ft per year, over 20 years, and at a 5 percent discount rate, the PV of the productivity benefits would be about \$36.89/sq ft for Certified and Silver level buildings, and \$55.33/sq ft for Gold and Platinum level buildings.

Other benefits: Regarding water-related savings (from the state's perspective), there are additional costs of developing new supplies and delivering water to the end user. Water-related savings can re-

duce these significant costs. Additionally, four of the attributes associated with green building design (increased ventilation control, increased temperature control, increased lighting control and increased day lighting), have been positively and significantly correlated with increased productivity.

Metrics Used: Energy savings, water-related savings, GHG emissions, implementation costs.

Applicability to the Army: The Army could see a significant savings in its energy and water utilities through “greening” its buildings. They could also see a reduction of GHG Emissions and waste production.

“Achieving Silver LEED: Preliminary Benefit-Cost Analysis for Two City of Seattle Facilities Final Report”*

Project Description: The purpose of this study was to evaluate the impacts of the Sustainable Building Policy on two projects nearing completion in early 2003: the Seattle Justice Center and Marion Oliver McCaw Performance Hall. Study objectives include: (1) enumerating the costs and benefits of LEED Silver certification, (2) calculating life-cycle benefit-cost ratios for each project within data constraints, and (3) providing early feedback on the effects of the Sustainable Building Policy.

Objectives relative to performance: For the two studied projects combined, LEED-influenced actions are cost-effective. The analysis concluded that the City of Seattle’s investment of an additional \$2.64 million to obtain LEED Silver certification for the Justice Center and McCaw Hall projects is cost-effective when examined over a 25-year period. The combined long-term net benefits from LEED for both projects from the perspective of the City General Fund are 49 to 116 percent higher (depending on the discount rate assumed) than the initial net costs associated with certification. The one thing that affected the cost-effectiveness of LEED actions was the occupancy rates. From the City General Fund perspective, the McCaw Hall project was only marginally cost-effective, with benefits ranging from 26 percent less to 7 percent more than the costs. Benefits for the Justice Center project, by comparison, exceeded costs by 93 to 180 percent.

* SBW Consulting, Inc. April 2003. *Achieving Silver LEED: Preliminary Benefit-Cost Analysis for Two City of Seattle Facilities Final Report*. Seattle Office of Sustainability and Environment.

Cost investment paid to achieve green: The overall increase in the initial net cost of the two projects that can be attributed to the influence of LEED certification is \$2,637,500, of which the Oliver McCaw Performance Hall was \$909,400 and the Seattle Justice Center, \$1,728,100. This represents about 1.2 percent of their combined project budgets. The sustained net benefits are \$3,138,400 to \$4,542,700 at 6 and 2 percent discount rates, respectively.

Design or actual performance compared to a non-LEED® building solution: For McCaw Hall, actions associated with Energy & Atmosphere—energy efficiency measures, commissioning, and savings verification—account for nearly two-thirds of the initial net cost. IEQ and Innovation & Design Process actions also accounted for sizeable portions—20 and 13 percent, respectively. For the Justice Center, actions associated with Energy & Atmosphere accounted for the 56 percent of the initial cost. IEQ and Innovation & Design Process actions account for 11 and 29 percent, respectively.

For both projects, Water Efficiency and Materials & Resources actions made up a negligible share of the cost. For McCaw Hall, the sustained net benefits ranged from \$581,500 to \$834,700, for the 6 and 2 percent discount rates, respectively, nearly all of which were classified as direct, observable financial impacts. On a normalized basis, the benefits range from \$1.97-2.83/sq ft. For the Justice Center, the sustained net benefits ranged from \$2,556,900 to \$3,708,000, only 40 percent of which was classified as direct, observable financial impacts. The percentage of primary benefits is relatively low because potential occupant productivity benefits, classified as indirect costs and benefits make up over half of the total project benefits. On a normalized basis, the benefits range from \$8.52 – 12.36/sq ft. The two projects combined produced an aggregate benefit of \$3,138,400 to \$4,542,700, about 51 percent of which is direct, observable financial impacts.

Other benefits: This study did not provide any additional benefits.

Metrics Used: Implementation cost, energy savings, water-related savings.

Applicability to the Army: This analysis showed that many projects can achieve sustainable design within their initial budget and develop some direct, observable financial impacts sustained benefits over a significant period.

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